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Application No. : 09/785,944
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Customer No.: 20,995

REPLY BRIEF

Applicant	:	Martin E. Fermann
Appl. No	:	09/785,944
Filed	:	February 16, 2001
For	:	MODE-LOCKED MULTI-MODE FIBER LASER PULSE SOURCE
Examiner	:	Hrayr A. Sayadian
Art Unit	:	2815
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/Steven P. Ruden/
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Sir:

This Reply Brief is submitted in response to the Examiner's Answer dated September 21, 2009. The arguments and responses presented in this Reply Brief supplement those presented in the Amended Appeal Brief submitted September 23, 2008. Thus, for the reasons discussed below as well as the reasons set forth in the Amended Appeal Brief, Appellant respectfully submits that the Examiner's rejections are improper.

Appellant sets forth below updates of the following sections of the Amended Appeal Brief:

> Section II, Related Appeals and Interferences and Section X, Related Proceedings Appendix; Section III, Status of Claims and Section VIII, Claims Appendix; Section IV, Status of Amendments; Section VI, Grounds of Rejection to be Reviewed on Appeal; Section VII, Argument; and Section IX, Evidence Appendix.

The following sections remain as set forth in the Amended Appeal Brief and are not reproduced herein:

Section I, Real Party in Interest; and Section V, Summary of Claimed Subject Matter.

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II. RELATED APPEALS AND INTERFERENCES

(1) IMRA America owns U.S. Patent No. 5,818,630 (the '630 Patent), which has the same inventors as the present application and is incorporated by reference therein. IMRA America is currently involved in litigation with IPG Photonics Corporation ("IPG") relating to the '630 Patent. The litigation, *IMRA America, Inc. v. IPG Photonics Corporation*, was filed in federal court in the Eastern District of Michigan on November 16, 2006 (Case No. 2:06-cv-15139).

On December 21, 2007, IPG requested ex parte reexamination of the '630 Patent. This initial request for reexamination and a subsequent corrected request dated January 22, 2008 were not granted for failure to comply with reexamination request filing requirements. IPG filed a replacement request for ex parte reexamination on March 12, 2008, which was granted by the Patent Office on June 3, 2008 as Application No. 90/008,971, filed March 12, 2008.

On April 3, 2008, the litigation was stayed pending completion of the reexamination of the '630 Patent. The reexamination has been completed, and an ex parte reexamination certificate was issued on October 27, 2009 that confirmed the patentability of all the claims in the original patent (as well as additional claims added during the reexamination). On October 13, 2009, the litigation stay was lifted and the litigation was reopened.

On August 19, 2009, IPG requested another ex parte reexamination of the '630 Patent.. This reexamination was assigned Application No. 90/010,650. IPG's request for ex parte reexamination was denied November 13, 2009.

(2) The present application is part of the following family of applications, all owned by IMRA America:

No.	Serial Number	Title	Filed	Relationship/ Status
1.	09/199,728	MODE-LOCKED MULTI-MODE FIBER LASER PULSE SOURCE	11/25/1998	Parent Application; Issued as U.S. Pat. No. 6,275,512
2.	09/785,944	MODE-LOCKED MULTI-MODE FIBER LASER PULSE SOURCE	02/16/2001	Continuation of the '728 Application; **The present application**
3.	10/424,220	MULTI-MODE FIBER AMPLIFIER	04/25/2003	Continuation of the '728 application and the '944 application; Pending
4.	10/850,509	MODE-LOCKED MULTI-MODE FIBER LASER PULSE SOURCE	05/20/2004	Continuation of the '728 application, the present application, and the '220 application; Abandoned

(3) IMRA America also owns the following applications that contain subject matter relating to multi-mode fibers and systems.

No.	Serial Number	Title	Filed	Relationship/ Status
1.	08/822,967	QUASI-PHASE-MATCHED PARAMETRIC CHIRPED PULSE AMPLIFICATION SYSTEMS	03/21/1997	Issued as U.S. Pat. No. 6,181,463
2.	09/116,241	QUASI-PHASE-MATCHED PARAMETRIC CHIRPED PULSE AMPLIFICATION SYSTEMS	07/16/1998	CIP of (1); Issued as U.S. Pat. No. 6,208,458
3.	09/317,221	MICROCHIP YB FIBER HYBRID OPTICAL AMPLIFIER FOR MICRO-MACHINING AND MARKING	05/24/1999	CIP of (2); Abandoned
4.	10/645,662	MICROCHIP YB FIBER HYBRID OPTICAL AMPLIFIER FOR MICRO-MACHINING AND MARKING	08/22/2003	Continuation of (3); Abandoned

No.	Serial Number	Title	Filed	Relationship/ Status
5.	10/927,374	HIGH ENERGY OPTICAL FIBER AMPLIFIER FOR PICOSECOND-NANOSECOND PULSES FOR ADVANCED MATERIAL PROCESSING APPLICATIONS	08/27/2004	Continuation of (4); Abandoned
6.	10/958,593	OPTICAL AMPLIFIER SYSTEM FOR MICROMACHINING AND MARKING	10/06/2004	Continuation of (4); Abandoned
7.	11/141,704	MICROCHIP-YB FIBER HYBRID OPTICAL AMPLIFIER FOR MICRO-MACHINING AND MARKING	06/01/2005	Continuation of (4); Issued as U.S. Pat. No. 7,576,909
8.	11/372,185	MICROCHIP-YB FIBER HYBRID OPTICAL AMPLIFIER FOR MICRO-MACHINING AND MARKING	03/10/2006	Continuation of (6); Pending
9.	11/339,679	FIBER LASER SYSTEM WITH INCREASED OPTICAL DAMAGE THRESHOLD	01/26/2006	Continuation of (7); Issued as U.S. Pat. No. 7,190,511
10.	11/643,760	MICROCHIP-YB FIBER HYBRID OPTICAL AMPLIFIER FOR MICRO-MACHINING AND MARKING	12/22/2006	Continuation of (9); Issued as U.S. Pat. No. 7,492,508

III. STATUS OF CLAIMS

Claims 1-8, 10, 11, 13-26, 30-33, 35-46, 50, 55-57, and 59-66 were previously pending in this appeal. Appellant is submitting concurrently with this Reply Brief an Amendment Submitted Pursuant to 37 C.F.R. § 41.33(b)(1) to cancel Claims 7-33, 35-50, and 57-66 for the purpose of facilitating expeditious and compact appeal of this application. Accordingly, after entry of this Amendment, Claims 1-6, 55, and 56 remain pending for appeal. A copy of Claims 1-6, 55, and 56 is attached hereto as Claims Appendix VIII. Claims 1-6, 55, and 56 stand rejected.

IV. STATUS OF AMENDMENTS

As discussed in Section III, Appellant is submitting concurrently with this Reply Brief an Amendment Submitted Pursuant to 37 C.F.R. § 41.33(b)(1) to cancel Claims 7-33, 35-50, and 57-66 for the purpose of facilitating expeditious and compact appeal.

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

The "Grounds of Rejection" section extending from page 4 to page 14 of the Examiner's Answer substantially repeats the grounds for rejection set forth in the Final Office Action as enumerated sections 2-5, 7, 13-21, and 25. The "Grounds of Rejection" section of the Examiner's Answer does not include grounds of rejection enumerated as sections 6, 8-12, and 22-24 of the Final Office Action. Although grounds of rejection 6, 8-12, and 22-24 of the Final Office Action were not specifically withdrawn in the Examiner's Answer, the Board may treat these grounds of rejection as having been dropped, because they were not included in the Examiner's Answer. See, M.P.E.P. § 1207.02. Should the Board decide to consider these grounds of rejection, Appellant maintains the positions set forth in the Amended Appeal Brief regarding these grounds of rejection.

As noted above, Claims 7-33, 35-50, and 57-66 have been canceled to facilitate expeditious and compact appeal. Claims 1-6, 55, and 56 remain pending.

Accordingly, the following grounds for rejection remain to be reviewed on appeal:

1. The rejection of Claim 1 under 35 U.S.C. § 102(b) as being anticipated by U.S. Patent No. 5,422,897 to Wyatt et al. ("Wyatt").

2. The rejection of Claims 2-6 under 35 U.S.C. § 103(a) as obvious over Wyatt in view of U.S. Patent No. 5,627,848 to Fermann et al. ("Fermann III," using the Examiner's naming convention from the Final Office Action and the Examiner's Answer), as motivated by De Souza, et al. "Saturable Absorber Modelocked Polarisation Maintaining Erbium-Doped Fibre Laser" ("De Souza").

3. The rejection of Claim 55 under 35 U.S.C. § 103(a) as obvious over Wyatt in view of Fermann III or in view of U.S. Patent No. 4,832,437 to Kim, et al. ("Kim").

4. The rejection of Claim 56 under 35 U.S.C. § 103(a) as obvious over Wyatt in view of Fermann III or Kim, further in view of Fermann III.

VII. ARGUMENT

For at least the reasons explained below and the reasons set forth in the Amended Appeal Brief, Appellant respectfully submits that the rejections in the Final Office Action are improper and requests that these rejections be reversed.

1. The rejection of Claim 1 under 35 U.S.C. § 102(b) as being anticipated by Wyatt (U.S. Patent No. 5,422,897)

Claim 1

In order for a reference to anticipate a claim, the reference must disclose "not only all of the limitations claimed but also all of the limitations arranged or combined in the same way as recited in the claim." *Net MoneyIn, Inc. v. Verisign, Inc.*, 545 F.3d 1359, 1371 (Fed. Cir. 2008) (emphasis added). See, also, *M.P.E.P.* § 2131. Further, patent claims may have functional rather than structural limitations. *In re Swinehart*, 439 F.2d 210, 212; 160 U.S.P.Q. 226 (CCPA 1971) ("there is nothing intrinsically wrong with the use of such a technique in drafting patent claims"). See, also, *M.P.E.P.* §§ 2173.01 and 2173.05(g) (functional language does not render a claim improper).

Claim 1 recites, among other limitations, "a pump coupled to said cladding for exciting said gain medium" of a multi-mode optical fiber. Coupling the pump to the cladding of the multimode fiber so that it excites the gain medium has several advantages. Cladding pumping not only permits much higher pump power to be input to the fiber (e.g., due to the generally much larger area of the cladding relative to the core) but, by coupling the pump light to the cladding so that the pump light excites the gain medium, the laser advantageously outputs much higher power.

Appellant respectfully contends the underlined part of the above-quoted limitation is an entirely permissible functional limitation that specifies what the pump coupled to the cladding *does* (excites the gain medium) rather than by what the pump *is*. See, *Swinehart* at 212.

However, the Examiner has given little, if any, weight to the underlined part of the limitation quoted above. For example, the Examiner states "the 'for exciting ...' is an intended use language not necessarily narrowing the limitation pump." Examiner's Answer, p. 7. The Examiner also states "[t]he claimed language is 'a pump coupled to said cladding,'" which simply ignores the "for exciting said gain medium" limitation of Claim 1. Examiner's Answer, p. 16. The "for exciting said gain medium" language cannot be ignored, because the language acts to further define the nature of the coupling of the pump to the cladding. This language is not a mere statement of intended use that is optional and does not limit the claim. See, *M.P.E.P.* §§ 2106 and 2111.04.

By improperly ignoring this functional limitation of Claim 1, the Examiner has failed to show that Wyatt discloses each and every limitation "arranged or combined in the same way as recited in the claim" and therefore has failed to show that Wyatt anticipates Claim 1. See, also, *M.P.E.P.* § 2173.05(g) (the examiner must evaluate and consider a functional limitation for what it fairly conveys to a person of ordinary skill in the pertinent art). For at least this reason, the rejection of Claim 1 is improper and should be reversed.

The rejection of Claim 1 is improper for additional reasons. The Examiner has not established that Wyatt explicitly discloses that *any* pump light is "coupled to said cladding for exciting said gain medium." Therefore, the burden is on the Examiner to provide evidence that a person of ordinary skill would recognize that this feature of Claim 1 is *inherent* in Wyatt. Inherency requires that the Examiner establish this feature is *necessarily* present in Wyatt. See, *In re Robertson*, 169 F.3d 743, 745, 49 U.S.P.Q. 2d 1949, 1950-51 (Fed. Cir. 1999). Importantly, inherency may not be established by "probabilities and possibilities." *Id.* "The mere fact that a certain thing may result from a given set of circumstances is not sufficient." *Continental Can Co. v. Monsanto Co.*, 948 F.2d, 1264, 1269, 20 U.S.P.Q. 2d 1746, 1749 (Fed. Cir. 1991).

Appellant respectfully contends the Examiner has failed to show that Wyatt's laser system necessarily includes "a pump coupled to said cladding for exciting said gain medium." Appellant initially points out that Wyatt states that Wyatt's pump has a coupling efficiency into Wyatt's

multimode fiber waveguide of about 50%. Wyatt, col. 6, lines 6-9. From this 50% efficiency, the Examiner concludes (without citation to any authority) that "whatever [pump light] is not coupled into the multimode fiber in Wyatt is coupled to the outside of the multimode fiber, and that outside includes the cladding." Examiner's Answer, p. 17. In short, the Examiner assumes that Wyatt achieved a perfect, 100% efficiency of coupling pump light into the fiber, with 50% coupled to the core and 50% coupled to the cladding. The Examiner simply discounts Appellant's contention on page 25 of the Amended Appeal Brief that Wyatt's 50% efficiency could be adequately explained by well known optical loss mechanisms such as, for example, absorption, reflection, refraction, scattering, diffraction, and optical misalignments. See, Examiner's Answer, p. 16. Appellant contends it is possible that very little, if any, pump light couples to the cladding of Wyatt's fiber due to these loss mechanisms. Accordingly, Appellant respectfully submits that the Examiner has failed to show that Wyatt's system *necessarily* couples pump light into a fiber cladding.

However, even assuming for the sake of argument only, that some fraction of Wyatt's pump light enters Wyatt's cladding, the Examiner has failed to show that this light *necessarily* excites the gain medium. As discussed above, the Examiner simply ignores the functional limitation recited in Claim 1 and does not establish that pump light in Wyatt's cladding *necessarily* would have suitable characteristics (e.g., intensity, ray geometry, etc.) to excite the gain medium of the multimode optical fiber recited in Claim 1. Accordingly, for at least these additional reasons, the rejection of Claim 1 is improper and should be reversed.

2. The rejection of Claims 2-6 under 35 U.S.C. § 103(a) as obvious over Wyatt in view of Fermann III, as motivated by De Souza.

Claims 2-6

These claims depend from and include all the limitations of Claim 1 as well as other limitations which further define the scope of the inventions in these claims. Claim 1 recites, among other limitations, "a pump coupled to said cladding for exciting said gain medium" of a length of multi-mode optical fiber. As discussed above in Ground for Rejection 1, Appellant

respectfully submits that the Examiner has failed to demonstrate that Wyatt discloses "a pump coupled to said cladding for exciting said gain medium" as recited in Claim 1 and claims depending therefrom. The Examiner does not contend that Fermann III or DeSouza make up for the deficiencies of Wyatt with regard to this limitation of Claim 1. Therefore, Appellant respectfully submits that the Examiner has not established a prima facie case of obviousness of Claims 2-6, at least because the cited references, alone or in combination, do not teach or suggest all the limitations of the rejected claims. For at least this reason, the rejections of Claims 2-6 are improper and should be reversed.

"With regard to rejections under 35 U.S.C. § 103, the examiner must provide evidence which as a whole shows that the legal determination sought to be proved (i.e., the reference teachings establish a prima facie case of obviousness) is more probable than not." *M.P.E.P.* § 2142. Accordingly, "the key to supporting any rejection under 35 U.S.C. § 103 is the clear articulation of the reason(s) why the claimed invention would have been obvious." *M.P.E.P.* § 2142; see *KSR International Co. v. Teleflex, Inc.*, 550 U.S. 398, 418; 82 USPQ 2d 1385,1395-97 (2007).

Further, "rejections on obviousness grounds cannot be sustained by mere conclusory statements; instead, there must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness." *In re Kahn*, 441 F. 3d 977, 988, 78 U.S.P.Q.2d 1329, 1336 (Fed. Cir. 2006). The Examiner also must show that a person of ordinary skill using the combined teachings would have had a reasonable expectation of success of achieving the claimed invention. *DyStar Texttilfarben GmbH & Co. Deutschland KG v. C.H. Patrick Co.*, 464 F.3d 1356, 1360 (Fed. Cir. 2006).

Claims 2-6 depend from Claim 1 and include "a mode locking mechanism positioned on said cavity axis." The Examiner admits that Wyatt does not disclose modelocking. See, Office Action mailed September 25, 2006, page 16. Appellant contended in the Amended Appeal Brief that the Examiner has not provided articulated reasons that the asserted combination of Wyatt, Fermann III, and De Souza would provide a person of ordinary skill in the art with a reasonable expectation of success of modelocking the laser recited in these claims. For example, to the

extent that Fermann III and De Souza disclose modelocking, it is in the context of *single-mode* fibers and not *multi-mode* fibers as recited in Claims 2-6, and the Examiner has not provided legally sufficient reasoning why such single-mode teachings are relevant to mode-locking multi-mode fiber lasers. Amended Appeal Brief, pp. 30-31.

In the Examiner's Answer (page 18), the Examiner asserts that Appellant's arguments regarding lack of reasonable expectation of success are contradicted by the disclosure in Appellant's application. Appellant strongly disagrees. To support his assertion, the Examiner first notes that the application incorporated by reference an article to Griebner, which purportedly discloses modelocking multimode fiber lasers in a sentence that describes the work of "reference 7, published in 1994, as disclosing the modelocking multimode fiber lasers." Examiner's Answer, p. 18. Reference 7 is an article by Glas et al. that is not of record in the application and is not included in the Examiner's list of Evidence Relied upon in Section (8) of the Examiner's Answer. For the convenience of the Board, Appellant includes a copy of the Griebner and Glas articles in the Evidence Appendix attached hereto. The Griebner article is of record in this application. By submitting the Glas article, Appellant is not intending to include any new or non-admitted evidence but is simply responding to the Examiner's comments about Glas, which the Examiner raised for the first time in the Examiner's Answer. Accordingly, Appellant believes this Reply Brief is in full compliance with 37 C.F.R. § 41.41.

The Examiner simply asserts that Griebner through its reference to Glas discloses that modelocking multimode fiber lasers had been achieved. Apart from making this bare assertion, the Examiner provides no explanation or even citation to the relevant portions of Glas that either contradict the disclosure of the application or establish a reasonable expectation of success for combining Wyatt, Fermann III, and De Souza to achieve the inventions recited in Claims 2-6. Appellant submits the Examiner's bare assertion and conclusory reference to Glas falls far short of the "articulated reasoning with some rational underpinning [required] to support the legal conclusion of obviousness." *Kahn* at 988. For at least this additional reason, the Examiner's rejections of Claims 2-6 should be reversed.

Appellant also contends that the Examiner's conclusory reference to Glas is misleading. Glas discloses a phase-coupled fiber array laser consisting of *150 separate fibers* with irregular center to center spacings and different lengths. Glas, p. 102, left column, lines 10-14. Modelocking lasted for 80 nanoseconds. Glass, p. 103, left column, lines 16-18; Figs. 4a, 4b. The Examiner has provided no reasons why a person of ordinary skill in the art would believe modelocking the 150 fiber array of Glas for 80 nanoseconds would have any relevance to modelocking the single fiber systems of Wyatt (using a multimode fiber) and Fermann III and De Souza (each using a single mode fiber). Glas is simply out of context and not relevant to the rejections of Claim 2-6.

3. The rejection of Claim 55 under 35 U.S.C. § 103(a) as obvious over Wyatt in view of Fermann III or in view of Kim (U.S. Patent No. 4,832,437)

<u>Claim 55</u>

Independent Claim 55 is a method including, among other limitations, "amplifying said light energy within said laser cavity in a <u>bent</u> multi-mode fiber." The Examiner admits that Wyatt does not disclose bending a multi-mode fiber and turns to Fermann III or Kim for purportedly teaching bent fibers. Office Action mailed September 25, 2006, page 17.

Wyatt's laser operates based on forcing the propagation of the fundamental mode down a multimode fiber that is "<u>nominally straight</u>," through the use of a feedback mechanism in a laser cavity. See, Wyatt, col. 7, lines 3-4 (emphasis added) and col. 8, lines 30-40; Amended Appeal Brief, pp. 33-36. Bending Wyatt's straight, multi-mode fiber would cause significant coupling of power into high order modes, which would render Wyatt's laser unsatisfactory for forcing oscillation of the fundamental mode and preventing mode coupling to higher order modes in Wyatt's laser. Wyatt, col. 8, lines 35-39. Accordingly, because the Examiner's proposed modification of bending Wyatt's nominally straight multimode fiber would render Wyatt's laser unsatisfactory, the Examiner has not established a *prima facie* case of obviousness. M.P.E.P. § 2132.01(VI). For at least this reason, the rejection of Claim 55 should be reversed.

In the Examiner's Answer, the Examiner attempts to turn Wyatt's teaching of nominally straight multimode fibers on its head. The Examiner asserts Wyatt teaches that if a level of ytterbium between 0.5 and 5.0 weight % is used, "fibers need not be <u>nominally</u> straight since their length is less than 1 meter." Examiner's Answer, p. 20 (emphasis in original). The Examiner's assertion is simply without merit.

Wyatt discovered the fundamental mode can be forced to propagate down a multimode fiber in a laser cavity "<u>for distances of up to one meter, if the fiber is nominally straight</u>." Wyatt, col. 7, lines 1-4 (emphasis added). Wyatt does not qualify these unambiguous requirements that the fiber be nominally-straight and shorter than one meter based on dopant level in the fiber, as asserted by the Examiner. With regard to dopant level, Wyatt's apparent concern is that for lower dopant levels, fiber lengths *greater than one meter* would be required to achieve the optical gain required for a practical laser system. However, Wyatt does not disclose how dopant level in the fiber will affect mode coupling in a laser. For longer fiber lengths, the Wyatt laser system would not produce emission only in the fundamental mode (due to significant coupling of power into higher order modes). See, Wyatt, col. 7, lines 1-5 and lines 6-37; Abstract. For the particular case of the dopant ytterbium, Wyatt states "a level of ytterbium between 0.5 and 5.0 weight % the length of the multimode fibre would typically <u>not need to be as great as 1 meter</u>, and thus fibre length is <u>not</u> a significant constraint in terms of performance reduction for the present system." Wyatt, col. 7, line 67 – col. 8, line 3 (emphasis added). Therefore, in contradistinction to the Examiner's assertion, Wyatt teaches that <u>short</u> (less than one meter), <u>nominally straight</u>, <u>ytterbium-doped</u> fibers can be used in the laser cavity of Wyatt's laser system.

Accordingly, Appellant respectfully submits that bending Wyatt's nominally straight fiber (according to the Examiner's asserted combination of Wyatt, Fermann III, and Kim) would not only fundamentally change the principle of operation of Wyatt's laser but would also render Wyatt's laser unsatisfactory for forcing oscillation in only the fundamental mode. Wyatt, col. 3, lines 55-56; col. 8, lines 35-39. For at least these additional reasons, the Examiner has not established a *prima facie* case of obviousness, and the rejection of Claim 55 should be reversed.

4. The rejection of Claim 56 under 35 U.S.C. § 103(a) as obvious over Wyatt in view of Fermann III or Kim, further in view of Fermann III

Claim 56

Claim 56 recites a method as defined in independent Claim 55 "additionally comprising mode locking said light energy." As discussed above in Ground for Rejection 4, Appellant respectfully submits independent Claim 55 is nonobvious. Claim 56 is patentable at least in view of its dependency from a patentable independent claim. *In re Fine*, 837 F.2d 1071, 1076 (Fed. Cir. 1988) ("[d]ependent claims are nonobvious under section 103 if the independent claims from which they depend are nonobvious.") For at least this reason, the rejection of Claim 56 is improper and should be reversed.

With regard to the rejection of Claim 56, page 22 of the Examiner's Answer refers to the Examiner's arguments regarding modelocking set forth with reference to Claims 2-6 (see Grounds for Rejection 2 set forth above). For at least the reasons discussed in Ground for Rejection 2, Appellant respectfully submits the cited references do not render obvious a method "additionally comprising mode locking said light energy." Accordingly, Appellant respectfully requests reversal of the rejection of Claim 56 for this additional reason.

Conclusion

For at least the reasons set forth above, Appellant respectfully submits that the rejections of Claims 1-6, 55, and 56 are improper, and request that these rejections be reversed.

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VIII. CLAIMS APPENDIX

1. A laser, comprising:

a cavity which repeatedly passes light energy along a cavity axis;

a length of multi-mode optical fiber having a cladding and doped with a gain medium and positioned along said cavity axis;

a pump coupled to said cladding for exciting said gain medium; and

an optical guide positioned on said cavity axis which confines the light amplified by said multi-mode optical fiber to preferentially the fundamental mode of said multi-mode optical fiber.

2. A laser as defined in Claim 1 additionally comprising a mode locking mechanism positioned on said cavity axis, wherein said mode locking mechanism comprises a passive mode locking element.

3. A laser as defined in Claim 2 wherein said passive mode locking element comprises a saturable absorber.

4. A laser as defined in Claim 3 wherein said saturable absorber comprises InGaAsP.

5. A laser as defined in Claim 3 additionally comprising a power limiter for protecting said saturable absorber.

6. A laser as defined in Claim 5 wherein said power limiter comprises a two photon absorber.

55. A method, comprising:

circulating light energy within a laser cavity;

amplifying said light energy within said laser cavity in a bent multi-mode fiber; and

confining said light energy within said laser cavity substantially to the fundamental mode of said multi-mode fiber.

56. A method as defined in Claim 55 additionally comprising mode locking said light energy.

IX. EVIDENCE APPENDIX

Appellant submits the following two articles referenced on page 18 of the Examiner's Answer in **Appendix 1** attached hereto.

(1) Griebner et al., "Efficient laser operation with nearly diffraction-limited output from a diode-pumped heavily Nd-doped multimode fiber," Optics Letters, Vol. 21, no. 4, February 15, 1996, pp. 266-268.

Griebner was incorporated by reference in the application as filed, on page 6, line 24, and was cited in an Information Disclosure Statement entered by the Office on June 12, 2006.

(2) Glas et al., "Mode-locked picosecond pulse generation from a phase-coupled fibre array laser," Optics Communications, vol. 109, June 15, 1994, pp. 101-108.

The Examiner comments on the Glas reference on page 18 of the Examiner's Answer. Appellant notes the Examiner did not list the Glas reference in the Examiner's Answer, Section (8), "Evidence Relied Upon." Appellant includes a copy of the Glas reference for the convenience of the Board. By submitting the Glas article, Appellant is not intending to include any new or non-admitted evidence but is simply responding to the Examiner's comments about the Glas reference, which the Examiner raised for the first time in the Examiner's Answer. Accordingly, Appellant believes this Reply Brief is in full compliance with 37 C.F.R. § 41.41.

APPENDIX 1

Efficient laser operation with nearly diffraction-limited output from a diode-pumped heavily Nd-doped multimode fiber

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Laser performance of a diode-pumped Nd-doped multimode phosphate-glass fiber is reported. The selection of the fundamental mode in a multimode fiber is demonstrated, resulting in laser emission that is close to diffraction limited and that is nearly independent of the pump power. The heavily Nd-doped fibers with core diameters of 100 μm and lengths between 13 and 32 mm deliver as much as 130 mW of cw output power at 1.053 μm. A total efficiency of 31% with respect to launched pump power has been achieved.

Different types of diode-pumped fiber laser arrangements, including fiber array lasers, are of increasing interest for compact and efficient systems, particularly because of their favorable thermal properties. Single-mode fiber lasers are widely recognized as an efficient means to generate light of the lowest-order mode; however, they are generally regarded as low-power devices because of the difficulty in coupling the power from the diode pump sources into the fibers' single-mode core. A significant improvement in scaling these devices to higher power levels has been demonstrated through the use of cladding pumping schemes.[1,2] Recently nearly 10 W of output power was obtained by use of a cladding-pumped Nd-doped silica fiber laser.[3]

The potential of multimode fibers to generate high output power has also been demonstrated. As much as 100 W of average power[4] and 1 MW of peak power in the Q-switched regime[5] have been achieved with a flash-lamp-pumped fiber-array laser, but with restrictions regarding the brightness. In this case the participating waveguide modes of each single fiber are coupled within a limited coherence volume because of the relatively high mode-conversion coefficient and the mode dispersion of the multimode fiber.[6] By the lateral coupling of the fibers a supermode can be generated with a random distribution in phase and amplitude but stable over the gain relaxation time, during which longitudinal-mode locking can be realized.[7]

The rather poor beam quality of such lasers is related to the inherent mode conversion in the multimode fibers. We have successfully overcome this problem by shortening the length of the multimode fibers to several millimeters. In this way the external resonator dominates the beam quality of the fiber laser. The relatively large active multimode core associated with a large acceptance angle provides an efficient means to capture pump light from a low-brightness diode pump source and ensures high-brightness laser output, if transverse-mode selection is possible.

As an alternative to the very long—as long as 50 m—cladding-pumped fiber lasers, active multimode fibers offer the advantage of highly efficient laser operation with relatively short gain elements. Laser operation with a sufficient beam quality with multimode fibers is also particularly relevant for crystal-fiber lasers because of the present limitation of drawing crystal fibers with diameters of less than 100 μm.[8]

In this Letter we report on theoretical considerations of the resonator design and experimental results concerning diode pumping of short and heavily Nd-doped multimode phosphate-glass fiber lasers capable of emitting diffraction-limited output.

The preceding introduction has indicated the need for a theoretical estimate for designing a laser based on multimode fibers to operate in the fundamental mode with high stability. For a core diameter $d_c \sim 100$ μm, which represents our specific case, more than 1000 waveguide modes can be generated in a passive fiber. To select the fundamental mode, we must drastically reduce the mode conversion. The number of generated waveguide modes is a function of the mode-conversion coefficient D_m (Ref. 9) and the fiber length l. D_m must be determined experimentally for the specific fiber; in our case D_m has been measured to be $\sim 11 \times 10^{-4}$ rad^2/m (bent, $l = 1$ m). To achieve an energy conversion in the transverse mode $m = 2$ of lower than $1/e^2$, the fiber length l must be

$$l < \frac{\lambda^2}{16 D_m d_c^2} < 7 \text{ mm}, \tag{1}$$

where $\lambda = 1053$ nm is the laser wavelength.

The propagation of the fundamental mode is described by the Bessel function $J_0(ur)$ inside the

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fiber and by the Gaussian function $A(r)$ outside the fiber. For the best fit, the following condition must be approximately fulfilled within the entrance face of the fiber:

$$A(r) \approx J_0(ur), \qquad u = \frac{d_c}{2}\sqrt{n_c^2 k^2 - \beta^2},$$
$$\beta = n_c k \sin\theta_1, \tag{2}$$

where u is the normalized transverse propagation constant, β is the propagation constant, n_c is the refractive index of the core, and k denotes the wave vector.[10] For the fundamental mode in the fiber, u yields ~2.44. The Gaussian beam is described by a beam waist w_0 adapted to the fundamental mode in the fiber, depending on the core diameter:

$$A(r) \approx \exp\left(-\frac{r^2}{w_0^2}\right),$$
$$\frac{2w_0}{d_c} = 0.65 + \frac{1.61}{V^{1.5}} + \ldots \Rightarrow 3.1 w_0 \approx d_c. \tag{3}$$

Here V represents the commonly used fiber parameter.

Having discussed the conditions of the fiber design we must further examine the requirements for mode selection by an external resonator. The Fresnel diffraction loss γ can be determined approximately for different transversal modes m as a function of the distance of the resonator mirror from the fiber end face dz by the relation $\gamma_m \sim m^2 \lambda dz / w_0^2$. To illustrate this behavior, we show in Fig. 1 the results of the calculation and a graphical explanation of the propagation direction θ for different modes m. Assuming a fundamental mode loss ($m = 1$) much less than 1% and a higher-order mode loss greater than 1%, it should be possible to select the fundamental mode for a mirror distance dz near 150 μm, as can be seen from Fig. 1. Relatively high dopant concentrations are required for efficient operation with short cavities. Therefore the laser system is based on phosphate-glass fibers doped with 2.0-wt.% Nd_2O_3 in the core—approximately 2 orders of magnitude higher than for doped silica fibers—with no doping in the cladding (Kigre preforms). The drawn fibers are of multimode structure ($d_c = 100$ μm) with a N.A. of 0.44 (Fiberware). The loss at the laser wavelength $\lambda = 1.053$ μm has been determined to be ≤4 dB/m. The pump source was a cw diode laser (Adlas Model DL 900) with a nominal maximum operating power behind the pigtail (200-μm diameter, N.A. = 0.22) of 0.6 W at 807 nm. To investigate the laser performance, we placed short fibers with cleaved ends between two flat dichroic mirrors. On the pump side a highly reflecting mirror for the laser wavelength and with transmission >93% for the pump radiation is applied, and for the output coupler a reflectivity of 96.8% at 1.053 μm is used. The fiber end face was butted against the mirror only on the pump side. Index matching was used to minimize loss and unwanted étalon effects. We achieved passive cooling by placing the fiber on a Cu heat sink. The experimental setup is shown in Fig. 2.

The pump light was launched into the fiber by an antireflection-coated two-element lens system that provides a 2:1 reduction scaling factor and reimages and pigtail's output onto the input face of the fiber laser. Approximately 70% of the incident pump power reaches the active fiber within the N.A. of 0.44. The fibers used here were 13 and 32 mm long, thus ensuring nearly complete pump light absorption in the fiber (absorption coefficient, 11 cm^{-1}).

The gain per unit pump power ($g_0 l / P_a$) for a single pass has been found to be 0.64/W, in good agreement with the calculated values.[11] This corresponds to a small-signal gain–length product $g_0 l$ of 0.252 for the maximum absorbed pump power P_a. As Fig. 3 shows, a maximum cw output power of 20 mW could be achieved for the 32-mm-long fiber. The overall loss per pass is therefore 5.4%. By shortening the fiber length to 13 mm we reduced the single-pass loss to 2.2%. The dependence of laser output on pump power striking the 13-mm-long fiber is essentially linear,

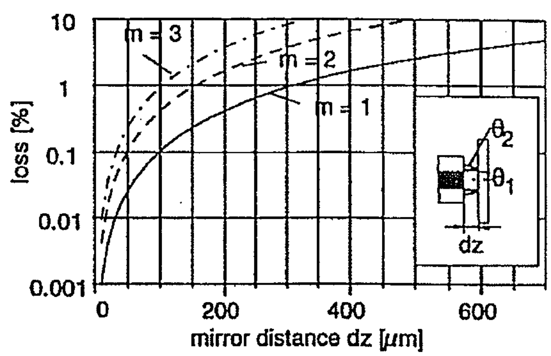

Fig. 1. Calculated Fresnel diffraction loss versus gap distance from the fiber to the resonator mirror dz for different transversal modes m.

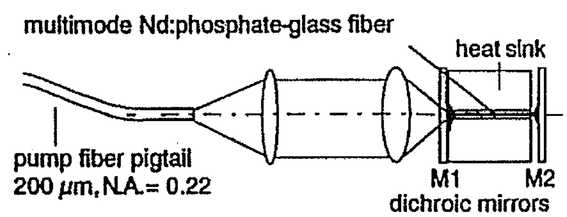

Fig. 2. Experimental setup of the diode-pumped Nd-doped fiber laser.

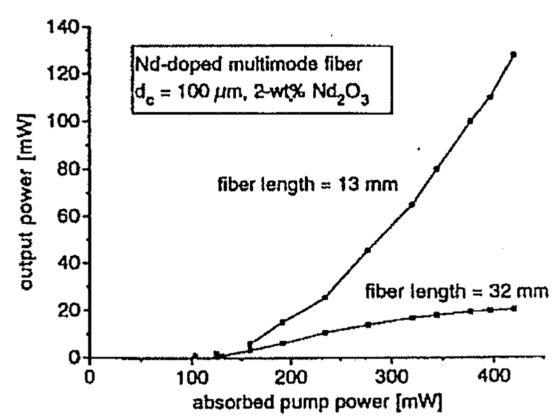

Fig. 3. Output power versus launched pump power for the cw fiber laser.

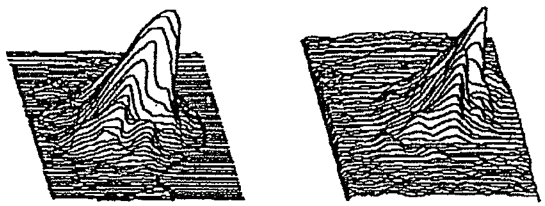

Fig. 4. Far-field distribution at different absorbed pump powers for the multimode fiber laser.

with a maximum cw output power of 130 mW and a threshold of ~98 mW at $\lambda = 1053$ nm (FWHM of 1 nm). This corresponds to a slope efficiency of 40% and a total efficiency of 31% with respect to launched diode power.

Considering the available pump power, the achieved output power represents approximately half of the theoretical limit. Because of the nonoptimized output coupling it should be possible to increase the efficiency of the laser. We could obtain further power scaling by pumping progressively harder with an adapted thermal management and by using a number of individual fiber lasers in a parallel arrangement.

As predicted, adjusting the gap distance between the fiber end face and the mirror surface to ~150 μm permits the generation of the fundamental mode. The mode discrimination is due to the mode selection by the Fresnel loss differences and the increase of waveguide losses for higher-order waveguides modes. It is interesting to note that the longer fiber also emits mostly in the fundamental mode. Compared with the case of a passive multimode fiber for which a maximum possible length of 7 mm was calculated following Eq. (1), the specific conditions in an active fiber (gain distribution) permit the generation of the fundamental mode in a somewhat longer fiber. The transverse-mode profile of the laser for two different pump powers (Fig. 4) shows that mainly the lowest-order waveguide modes are generated and that the main part of the energy is concentrated in a maximum solid angle of 1.5 times the diffraction limit, which corresponds to only 5% of the N.A. of the fiber. Altering the pump power did not produce any significant influence of the divergence, but a change among the different types of participating lowest-order modes occurred that is determined by thermal effects. When the pump laser was operated in a quasi-cw regime (duty cycle ≥ 10), thermal effects played a negligible role.

In conclusion, we have demonstrated efficient laser performance of a diode-pumped short Nd-doped multimode phosphate-glass fiber. With a compact longitudinal pump scheme, 70% of the pump power was absorbed in the active fiber. By using a fiber with a length of 13 mm and a core diameter of 100 μm we achieved a maximum cw output power of 130 mW with a total efficiency of 31% with respect to the launched pump power. The selection of the fundamental mode has been achieved mainly by Fresnel diffraction loss differences realized by adjustment of a small gap between the active fiber and the output coupling mirror. Laser emission at 1.053 μm that is close to diffraction limited and nearly independent of the pump power has been obtained.

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Mode-locked picosecond pulse generation from a phase-coupled fibre array laser

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Abstract

A phase-coupled fibre array laser in mode-locked in an external resonator applying active/passive loss modulation. The array consists of Nd-doped multimode phosphate glass fibres with *irregular* centre to centre spacings and *different* lengths. Pulses as short as 9 ps are generated with high peak powers of about 0.4 MW. The full divergence angle of the far field pattern amounts to about 0.07 rad.

1. Introduction

Mode-locked Nd:glass lasers represent a standard source of ultrashort pulses at a wavelength of 1 μm. Both flashlamp and laser pumped systems have been applied to generate pulses of pico- as well as subpicosecond duration. The length and the diameter of glass rods used in flashlamp pumped lasers have values of approximately 10 cm and up to 1 cm, respectively. For those dimensions, the low thermal conductivity of the material leads to a temperature gradient and thermal birefringence across the diameter of the laser rod that affects the lateral intensity distribution, the polarization and the temporal properties of the generated pulses. Furthermore, the maximum repetition rate of flashlamp pumped Nd:glass lasers is limited to a few s^{-1}.

Much better thermal properties are achieved with fibre lasers where the rod-like active medium is replaced by a single doped glass fibre or by an array of fibres. There is a number of papers dealing with short pulse generation in single rare earth doped fibres using cw diode pumping [1]. Mode locking of a single Nd-doped glass fibre laser has been recently improved applying dispersion compensation [2]. In fibre arrays, generation of average output powers higher than 50 W has been demonstrated [3]. An extended wavelength range between 0.65 and 3 μm can be covered by using a variety of dopants in the fibres forming the array.

In this paper, we describe a new type of laser generating ultrashort pulses which improves the properties of single fibre lasers in regard of the output power. In a first attempt, we have successfully investigated a mechanism which makes possible both a spatial coupling of about 150 emitters and a synchronisation of all the cavity modes taking part. In a further step we plan to make progress concerning the brightness of this radiation source. A fibre array laser enables the improvement of the brightness compared to a single fibre laser by proper selection of the lowest array supermode giving a single lobed farfield intensity pattern.

From the viewpoint of physics, fibre array lasers represent spatially extended nonlinear systems consisting of a large number (typically > 100) of cou-

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pled oscillators. Those multi-element systems allow the direct study of nonlinear interaction between individual emitters which is important for the generation of ultrashort pulses. For instance, synchronisation and phase-locking of modes in the common resonator play a key role for picosecond operation.

Phase coupling of different array members and radiation generation are influenced by both the ionic dopants and the nonlinear properties of the host. We report here for the first time, modelocked laser operation of an array of phase-coupled Nd:glass fibres. The array consists of approximately 150 fibres with irregular centre to centre spacings and different lengths that are transversally pumped by flashlamps. A combination of active/passive loss modulation yields pulses with a duration shorter than 9 ps (without dispersion compensation) with high single pulse energies of more than 2 μJ. The full cone far field angle of the radiation pattern amounts to about 0.07 rad.

2. Experimental

The experimental set-up is shown in Fig. 1. The resonator contains the fibre array, an acousto-optical modulator (AOM) and a dye cell for active/passive loss modulation. The lenses are designed in a way that the front and the rear face of the array are re-imaged on themselves, realising a confocal resonator with a wave guiding structure in the centre [4].

A colour filter preventing the dye from being exposed to the flashlamp uv-radiation serves as an output coupler.

The fibres are manufactured from phosphate glass with 9 wt% Nd_2O_3. They have a core diameter of about 30 μm, a cladding thickness of 5 μm and a numerical aperture of 0.18 [#1]. The combined losses at $\lambda = 1.05$ μm amount to $\approx 1\%$ cm^{-1}. The array is composed of about 150 fibres of varying length. Their mutual distances are not constant and light guiding is inherently multimode in character. The length of the array amounts to 22 cm with a pumped section of about 8 cm. Its ends are polished but not antireflection coated. A pump chamber containing two flash-

[#1] The performs are delivered by KIGRE Inc. Hilton Head Island, USA. The fibres have been pulled by FIBERWARE GmbH Berlin, Germany.

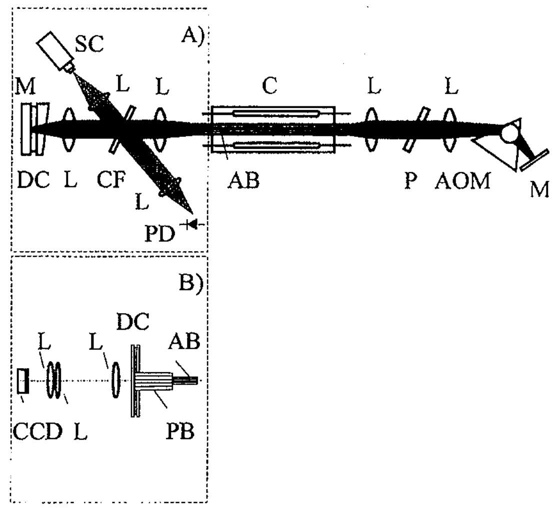

Fig. 1. Experimental set-up and detection equipment. The left hand part of the resonator could be modified to include a phase object (passive fibre bundle possessing picture transmission quality) as shown in the lower part. M: mirror ($R = 100\%$), DC: dye cell, L: lens, SC: streak camera, CF: colour filter, PD: photodiode, AB: active fibre bundle, C: pump cavity, P: polarizer, AOM: acousto-optical modulator, CCD: CCD camera, PB: passive fibre bundle.

lamps is used to excite the active medium transversally.

In the picosecond time regime, the pulse duration has been measured with both a Hamamatsu streak camera M2547, having a time resolution of $\leqslant 10$ ps and a C1785 model with a time resolution of about 2 ps. For slower transients, a photodiode in conjunction with a fast oscilloscope (HP 5471049) was used. The spectral widths of the pulses were obtained with the help of an OMA-system (Oriel, Insta Spec II; spectral resolution ~ 0.1 nm).

4. Results and discussion

In Fig. 2, we present a photograph of our fibre array illuminated with a standard microscope lamp. There is a limited number of fibres possessing the required high quality for light transmission. The low transmission of part of the array is mainly due to internal defects and misalignment of single fibres with respect to the optical axis of the array.

The radiation emitted by this array shows the well

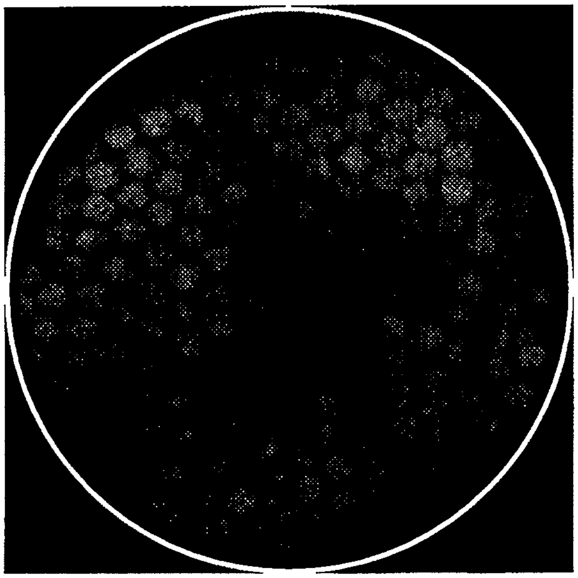

Fig. 2. Fibre array illuminated by a thermal light source.

known characteristics of Nd^{3+}-doped glass lasers. Without an intended loss modulation in the resonator, a random series of spikes appears (free running mode). In Fig. 3a, the output intensity is plotted as a function of time in the microsecond regime. Each fibre emits its characteristic spike sequence without taking notice of the neighbouring fibres. The incoherent superposition of the spikes belonging to the fibres taking part in the emission process gives rise to the intensity distribution shown in Fig. 3a, lasting for about 250 μs. Fig. 3b gives the corresponding near field intensity pattern. Matching the AOM frequency to the inverse round-trip time of a pulse in the resonator and choosing the appropriate dye concentration, the fibres of the array cease to emit random spikes. Instead, one single Q-switch pulse belonging to the array as a whole is emitted lasting for about 80 ns, cf. Fig. 4a. Necessarily, this pulse is distorted due to a slow sweep speed in the electronic recording process because we like to demonstrate that during the whole pumping cycle only one Q-switch pulse is emitted by the array. Consequently, the fibres do not longer emit independently from each other. This result was obtained with an AOM frequency of ~ 60 MHz, a AOM diffraction efficiency ~ 0.6, a small signal transmission of the dye solution of ~ 0.73 and a saturation intensity of ~ 50 MW cm^{-2}. The train

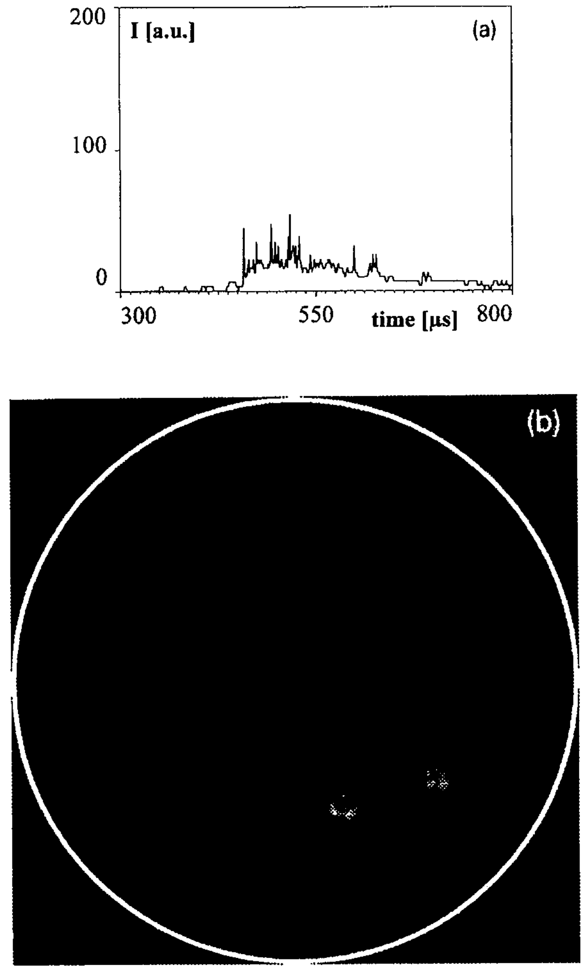

Fig. 3. (a) Temporal emission behaviour of the fibre laser array (free running mode, pumping at 1.12 times threshold). (b) Near field intensity distribution according to (a).

of ultrashort pulses under this pulse envelope is shown in Fig. 4b. Please note that the temporal width of the individual pulses is limited by the response time of the photodetector. Only in the case where all the fibres are spatially coupled and the cavity modes are phase-synchronised, *one and only one* train of ultrashort pulses is emitted. In Fig. 4c, the corresponding near-field distribution is shown. A comparison of Figs. 3b and 4c illustrate the important result that the number of fibres participating in the emission process is greatly enhanced in the coupled state. The decrease in the losses indicates that coupling is successfully performed by radiation injection seeding.

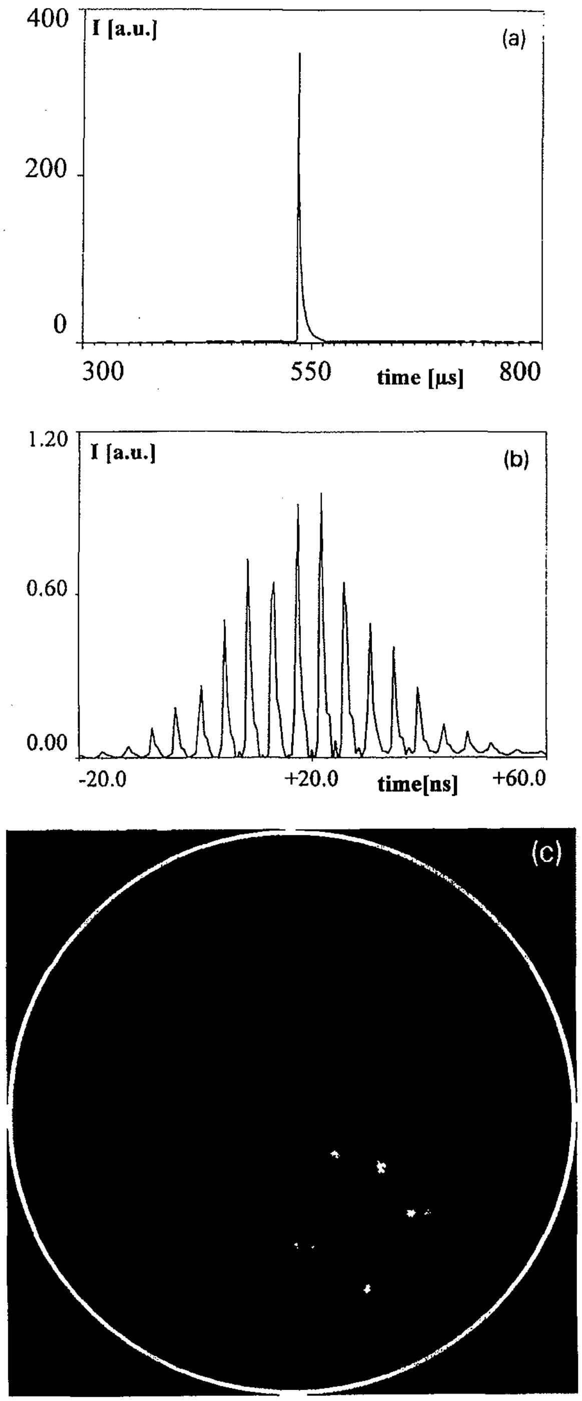

Fig. 4. (a) Q-switch pulse applying active/passive loss modulation. (The pumping conditions are the same as in Fig. 3.) (b) Time resolved pulse train with the overall envelope shown in (a). (c) Near field distribution of the laser output.

The spatial and temporal properties of the pulses emitted under these conditions were studied in detail. The near field of the array was imaged onto a reference plane and the emission of individual fibres was selected by placing fast photodiodes at the appropriate locations. The time resolved output of two fibres is shown in Fig. 5. Though lasing action does not start simultaneously in the fibres selected, there is a very good synchronisation of the short pulses within the time interval marked by the vertical lines in Fig. 5. Actually, this figure shows the most general case. All fibre couples investigated in this manner are temporally synchronised just as shown in Fig. 5. It is worthwhile to note, that different fibres do not simultaneously start emitting their pulses. If however, pulsed emission initiated in one or another fibre, it is completely synchronised with the fibres already emitting. Much better time resolution is required to study the degree of synchronisation on the picosecond time scale. Data recorded with a streak camera of a time resolution better than 10 ps are presented in Fig. 6. Here, the output of two fibres at different locations in the near-field of the array were imaged onto the slit of the streak camera. Fig. 6a gives the image of the two selected fibres recorded by the streak camera without time deflection. The time resolved measurements are shown in Fig. 6b confirming that the pulses emitted by different fibres of the array are temporally synchronised on a time scale of a few picoseconds. This finding strongly suggests an emission behaviour governed by phase-locked operation

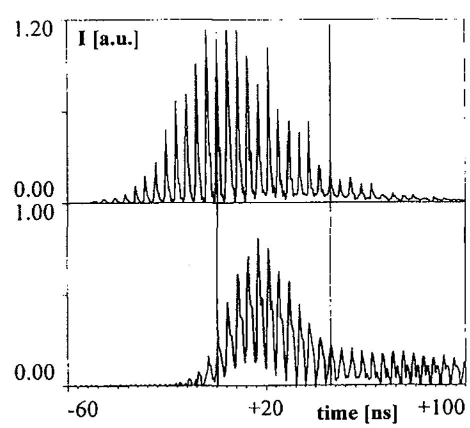

Fig. 5. Temporal correlation of pulse trains emitted by two arbitrarily selected fibres of the array (spatially resolved photodiode measurement).

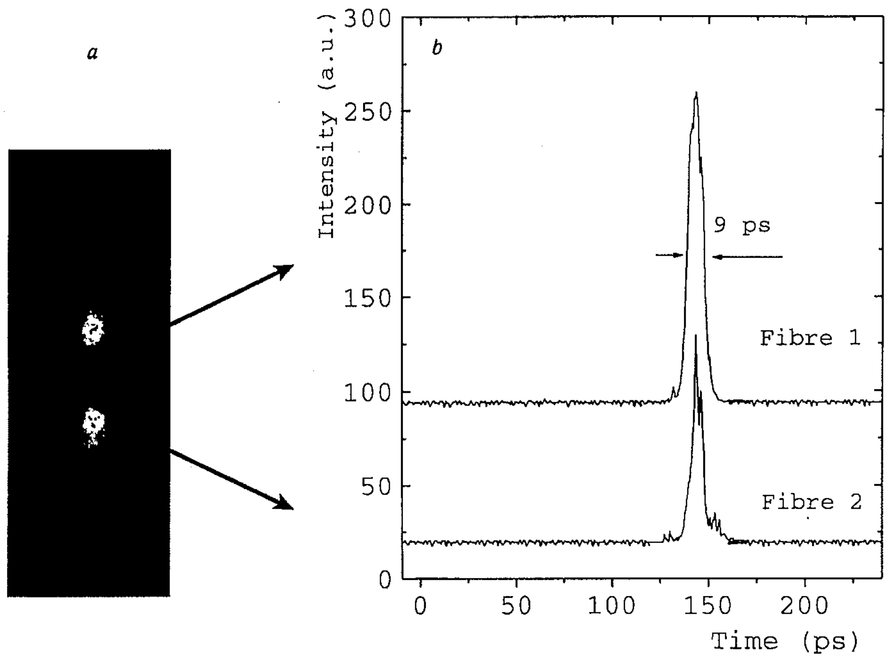

Fig. 6. (a) Near field image of two fibres of the array recorded with the streak camera without time deflection. (b) Temporally resolved output of the two fibres (the pulse duration is indicated).

of the array. Within the accuracy of our detection equipment we did not observe a timing jitter concerning pulses emitted by arbitrarily selected fibres.

The pulses shown in Fig. 6b have an envelope width of about 9 ps, close to the time resolution of the M2547 streak camera. We therefore repeated the measurement of the pulse duration with the Hamamatsu C1587 camera with a better temporal resolution of ~2 ps. This experiment gives a time envelope of the pulses of similar width, i.e. the duration of the individual pulses amounts to about 9 ps. Moreover, we have confirmed that the duration of the pulses emitted by the array, cf. Fig. 7 does not differ from those measured on single fibres, see Fig. 6b. A background free autocorrelation measurement [5] which is planned for the next future is more difficult to perform, because of the large divergence of the emitted radiation.

The spectral intensity distribution of the pulses is given in Fig. 8. This spectrum contains frequency components of the entire pulse train. The full width at half maximum has a value of about 1 nm. The maximum spectral width measured amounts to 5 nm. Using a time–bandwidth product $\Delta\tau\,\Delta\nu=0.35$, ac-

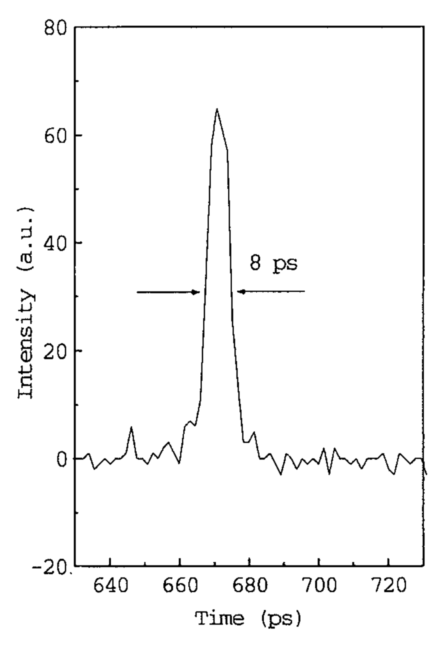

Fig. 7. Temporally resolved output of the fibre array laser.

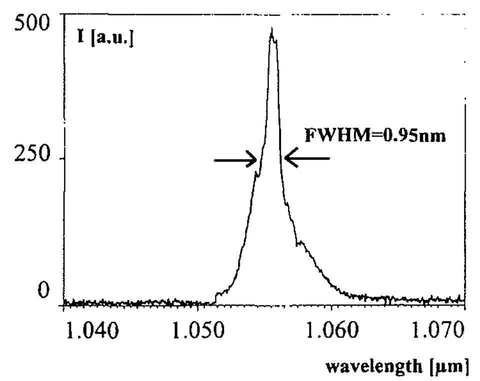

Fig. 8. Fibre array laser spectrum belonging to the pulse train containing the pulse shown in Fig. 7.

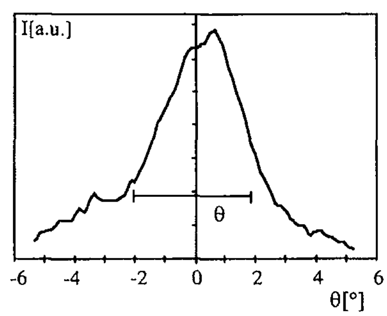

Fig. 9. One-dimensional cut through the far field intensity distribution of the fibre array laser.

cording to Ref. [3], one estimates a duration of 1.5 ps for a bandwidth-limited pulse of 0.95 nm width that is considerably shorter than the pulse duration of 9 ps found in our experiments. These findings suggest that the pulses are not bandwidth-limited due to chirping. Furthermore sub-picosecond fluctuations may exist in the temporal structure of the pulses in the train, resulting also in an excess spectral width. The amount of chirp may be roughly estimated. The frequency shift impressed on a wave going through 1 cm of a medium whose refractive index $\delta n = n_2 E^2$ changes at the rate $\delta n/\delta t$ is given by

$$\Delta\nu = -(1/\lambda)\,\delta n/\delta t\,.$$

For the sake of the argument let us take $\delta t = 5$ ps, a peak power density of about 10 GW/cm^2, $\delta n \approx 3\times10^{-6}$, $l = 22$ cm, $\lambda = 1053$ nm. From this we obtain $\Delta\nu \approx 10^{11}$ s^{-1} ($\Delta\lambda \approx 0.5$ nm) per round trip. On the rise and the fall of the Q-switch train the powers are considerable lower. Hence, the value just estimated shows that the measured bandwidths are considerably influenced by self-phase modulation. By compressing these pulses using standard techniques [6], their duration may be further reduced.

The spatial intensity distribution in the far-field of the fibre array laser was investigated in detail. The assessment of Fig. 4c reveals that the lasing fibres are neither regularly arranged nor emitting at the same intensity level. A collection of disordered emitters possessing equal diameters generate in the case of incoherent superposition a far field pattern which is of the same size compared to a single emitter [7], with an intensity value being proportional to the number of fibres participating in the emission process [8]. With respect to the substructure of the single fibre, cf. Fig. 4c one has not to expect a diffraction limited emission pattern. Nevertheless we obtain from the radiation emitted by the array a full divergence angle that is comparable to the diffraction limited emission of the single emitter.

Fig. 8 shows a one-dimensional cut through this distribution with a full cone angle of about 0.07 rad. The full cone angle of the central Airy-disc, defined at the first zero of the Fraunhofer diffraction pattern is given by $\Theta_f = 2.44\ \lambda/D$ where D is the fibre core diameter. With $D = 30$ µm we calculate $\Theta_f \approx 0.09$ rad for the single fibre. Obviously, the numerical value of the full divergence angle of the radiation pattern of the array is as small as diffraction limitation calls for the single emitter. For such a diffraction limited single peak in the far field of the fibre array to occur, at least a partial coherent operation of the array has to be assumed.

Moreover, the intensity distribution shows the well known speckle structure produced by a multielement radiator [9].

We complement the investigation of the temporal synchronisation of the fibre emitters by studying the spatial aspect of the correlated emission of the array. Generally, coherence properties can be characterised using speckle contrast techniques, being outlined in Ref. [10]. Using a modified experimental set-up, cf. Fig. 1, including box B instead of A, the speckle contrast V has been investigated by coherently illuminating a phase object (passive fibre bundle) with a cw, single frequency Nd-YAG laser and, secondly, by running the Nd-fibre array with the modified reso-

nator configuration (box B in Fig. 1). The emitted radiation was detected on the left hand side of the resonator (Fig. 1). In the former case, we obtain a contrast value $V=0.4$ from the speckle pattern. This rather low value is due to the limited spatial resolution of the detection equipment, the depolarisation within the fibres and the intensity nonuniformities over the emitting face of the array. Nevertheless, this value gives the upper limit for the contrast obtainable in our arrangement. In the latter case, the speckle contrast amounts to $V=0.13$ where the radiating areas in both cases are as similar as possible. The appearance of an interference structure with a speckle size determined by the radiating area on the resonator mirror is an indication that the fibres of the array emit in a correlated manner with a contrast depending on the spatial coherence between the fibres. During the pulse train a "frozen" speckle pattern with high contrast is obtained only if the frequencies of the spatially distributed emitters differ by $\Delta\nu \leqslant \frac{1}{2}T$ (T: duration of the pulse train), giving approximately $\Delta\nu \approx 5$ MHz. The reduced speckle contrast in the case of the array is mainly due to the temporal emission characteristics outlined in connection with Fig. 5.

If a single fibre acts as a pulse seeder it gives rise to a certain (speckled) background intensity level with a speckle size determined by the lasing modes in the fibre. Only those parts within the pulse train where all the fibres act synchronised (Fig. 5) are responsible for the speckle formation of a size determined by the total radiating area. Moreover, one has to take into account that the emission of individual fibres differ markedly in intensity (Fig. 4c), reducing the contrast even further.

We now discuss the mechanism synchronising the emission of different individual fibres in the array. Successful synchronisation of several emitters requires a well defined phase relationship between them with a unique frequency. The spatial mode pattern may then be well described by coupled mode theory, which generally holds true for evanescent wave-coupled diode lasers, where the field profiles can be expressed in terms of array (-super) modes. On the other hand, mode locking requires that the longitudinal modes must have the same frequency separation. Thus, in order for mode locking to occur, a nonlinear mechanism must be strong enough in a collection of lasers with different lengths to displace the mode frequencies in such a way that all modes have exactly the same frequency separation. There seems to be a close analogy between these two coupling mechanisms.

Our present understanding of the emission behaviour of the fibre array laser being made up of gain elements possessing different lengths (compared on a λ-scale) is based on the principle of pulsed injection seeding [11]. A single fibre or a small subgroup of emitters in the array serve as a master oscillator, reaching threshold at an earlier time than the other elements (cf. Fig. 5). During the build-up time of stimulated emission, the master oscillator reaches its second threshold first [12], therefore the injected intensity becomes higher than the spontaneous emission noise generated in the slave fibres. In this way, the initial conditions on the spatial and temporal modes of the fibres within the spatial coupling range are defined and a synchronised emission builds up in the active medium. After setting the initial conditions, the master is of little influence regarding the development of the radiation dynamics.

It is interesting to note that the effective losses in the laser system are considerably reduced in the case of coupled emission due to locking (Fig. 3b versus Fig. 4c).

The energy transfer between fibres, excluding evanescent wave coupling, is achieved with the help of the resonator elements (diffraction, aberrations). A refractive index grating which is caused by the saturable loss of the absorber and is located in the dye cell close to the mirror surface (Fig. 1) could enhance the coupling.

For the next future, we plan to improve both the brightness by reducing the far field divergence angle and increasing the output intensity.

6. Conclusions

We have demonstrated phase-coupled and mode-locked operation of a fibre array laser contained in an external resonator. Pulses of several μJ energy and duration $\leqslant 9$ ps are generated with spectral bandwidths up to 5 nm. The far field divergence angle amounts to about 0.07 rad. Spatially resolved measurements on different fibres clarify a temporally synchronised emission behaviour. The phase cou-

pled emission of the array members is further confirmed by a threshold reduction in the case of coupling and by the formation of an interference (speckle) pattern after incorporating a phase object in the resonator.

An outstanding property of the device under investigation is the spatial and temporal stability. We have neither found a transverse instability [13] nor a migration of the emission area across the array end face [14].

The dynamics of pulsed injection seeding will be discussed in a forthcoming publication.

Acknowledgements

We are indebted to Th. Elsässer for his comments and critical reading of the manuscript.

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X. RELATED PROCEEDINGS APPENDIX

(1) The litigation, *IMRA America, Inc. v. IPG Photonics Corporation*, filed in federal court in the Eastern District of Michigan (Case No. 2:06-cv-15139), was stayed on April 3, 2008 pending completion of the reexamination of the ‘630 Patent (Reexamination Application No. 90/008,971, filed March 12, 2008). The reexamination has been completed, and a Notice of Intent to Issue Ex Parte Reexamination Certificate (NIRC) was mailed July 21, 2009 that confirmed the patentability of all the claims in the original patent (as well as additional claims added during the reexamination). The District Court issued an Order Reopening Case and Lifting Stay on October 13, 2009. An ex parte reexamination certificate was issued on October 27, 2009. A copy of the NIRC, the District Court's Order, and the ex parte reexamination certificate for the ‘630 Patent are attached hereto in **Appendix 2**.

On August 19, 2009, IPG requested another ex parte reexamination of the ‘630 Patent. This reexamination was assigned Application No. 90/010,650. IPG's request for ex parte reexamination was denied by the Patent Office on November 13, 2009. A copy of the Order Denying Request for Ex Parte Reexamination is included in **Appendix 2**.

APPENDIX 2

8146693

UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
90/008,971	03/12/2008	5,818,630	16577-003RX1	5124

7590 07/21/2009

SUGHRUE MION ZINN MACPEAK & SEAS
2100 PENNSYLVANIA AVE. N.W.
WASHINGTON, DC 20037-3202

EXAMINER	
ART UNIT	PAPER NUMBER

DATE MAILED: 07/21/2009

Please find below and/or attached an Office communication concerning this application or proceeding.

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JUL 21 2009

CENTRAL REEXAMINATION UNIT

EX PARTE REEXAMINATION COMMUNICATION TRANSMITTAL FORM

REEXAMINATION CONTROL NO. 90/008,971.

PATENT NO. 5,818,630.

ART UNIT 3992.

Enclosed is a copy of the latest communication from the United States Patent and Trademark Office in the above identified *ex parte* reexamination proceeding (37 CFR 1.550(f)).

Where this copy is supplied after the reply by requester, 37 CFR 1.535, or the time for filing a reply has passed, no submission on behalf of the *ex parte* reexamination requester will be acknowledged or considered (37 CFR 1.550(g)).

Notice of Intent to Issue Ex Parte Reexamination Certificate	Control No. 90/008,971	Patent Under Reexamination 5,818,630	
	Examiner Deandra M. Hughes	Art Unit 3992	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

1. ☒ Prosecution on the merits is (or remains) closed in this *ex parte* reexamination proceeding. This proceeding is subject to reopening at the initiative of the Office or upon petition. *Cf.* 37 CFR 1.313(a). A Certificate will be issued in view of
   (a) ☒ Patent owner's communication(s) filed: *01 June 2009*.
   (b) ☐ Patent owner's late response filed: ______.
   (c) ☐ Patent owner's failure to file an appropriate response to the Office action mailed: ______.
   (d) ☐ Patent owner's failure to timely file an Appeal Brief (37 CFR 41.31).
   (e) ☐ Other: ______.

   Status of *Ex Parte* Reexamination:
   (f) Change in the Specification: ☐ Yes ☒ No
   (g) Change in the Drawing(s): ☐ Yes ☒ No
   (h) Status of the Claim(s):
      (1) Patent claim(s) confirmed: *1-49*.
      (2) Patent claim(s) amended (including dependent on amended claim(s)): ______
      (3) Patent claim(s) cancelled: ______.
      (4) Newly presented claim(s) patentable: 50 - 64
      (5) Newly presented cancelled claims: ______.
2. ☒ Note the attached statement of reasons for patentability and/or confirmation. Any comments considered necessary by patent owner regarding reasons for patentability and/or confirmation must be submitted promptly to avoid processing delays. Such submission(s) should be labeled: "Comments On Statement of Reasons for Patentability and/or Confirmation."
3. ☐ Note attached NOTICE OF REFERENCES CITED (PTO-892).
4. ☒ Note attached LIST OF REFERENCES CITED (PTO/SB/08).
5. ☐ The drawing correction request filed on ______ is: ☐ approved ☐ disapproved.
6. ☐ Acknowledgment is made of the priority claim under 35 U.S.C. § 119(a)-(d) or (f).
   a)☐ All b)☐ Some* c)☐ None of the certified copies have
   ☐ been received.
   ☐ not been received.
   ☐ been filed in Application No. ______.
   ☐ been filed in reexamination Control No. ______.
   ☐ been received by the International Bureau in PCT Application No. ______.

   * Certified copies not received: ______.
7. ☐ Note attached Examiner's Amendment.
8. ☒ Note attached Interview Summary (PTO-474).
9. ☐ Other: ______.

/Deandra M Hughes/ Primary Examiner, Art Unit 3992	/A. J. G./	

cc: Requester (if third party requester)

EX PARTE REEXAMINATION NIRC

1. The NIRC mailed June 26, 2009 is vacated. This is an *ex parte* NIRC of U.S. Patent No. **5,818,630**.

2. On July 2, 2009, Richard C. Turner (Patent Owner's Representative) telephoned the Examiner to note that the NIRC mailed July 26, 2009 did not address the claims (**claims 50-64**), which were newly added via the amendment filed June 1, 2009. Accordingly, this supplemental NIRC addresses the said newly added claims.

The Examiner sincerely regrets any inconvenience this may have caused either the Patent Owner or the Third Party Requester.

3. **Claims 1-3, 10-12, 24-25, 27-29, 31, 36-37, 39, and 46-49** were presented for reexamination. New **claims 50-64** were added in the amendment filed June 1, 2009. In addition, the "decision to reexamine any claim for which reexamination has not been requested lies within the sole discretion of the Office, to be exercised based on the individual facts and situation of each individual case. If the Office chooses to reexamine any claim for which reexamination has not been requested, it is permitted to do so." MPEP §2240. Here, **claims 4-9, 13-23, 26, 30, 32--35, 38, and 40-45** were not subject to reexamination. However, **claims 4-9, 13-23, 26, 30, 32--35, 38, and 40-45** are dependent upon **claim 1**, which has been confirmed as patentable as is stated below. Accordingly, the Examiner chooses to reexamine **claims 4-9, 13-23, 26, 30, 32--35, 38, and 40-45** based on their dependency on confirmed **claim 1** and the said claims are confirmed as patentable. As a result, **claims 1-49** are confirmed as patentable. **Claims 50-64** are allowed.

References Cited in this Action

4. Yang, Lih-Mei. *Generation and Amplification of Ultrashort Pulses in Erbium, Neodymium, and Thulium Fibers* ("**Yang**")

5. US 5,121,460 to Tumminelli published Jun. 9, 1992. ("**Tumminelli**")

Claims Confirmed

6. **Claims 1-49** are confirmed. **Claims 50-64** are allowed.

7. For at least reasons set forth in the arguments pertaining to the *mode converter* (Remarks, pgs. 16-20; the section titled A. **The Mode Converter Limitation**) and the **Neodymium fiber** of **Tumminelli** (Remarks, pgs. 25-26; section titled **Reason 2**), independent **claim 1** and its dependent **claims 2-49** are confirmed as patentable over the prior art of record and **claims 50-64** are allowed.

Information Disclosure Statement

8. The information disclosure statement submitted 6/17/08 has been considered.

Declaration of Dr. Wayne Harvey Knox

9. The declaration of Dr. Wayne Harvey Knox filed June 1, 2009 is noted. However, the declaration is moot because the claims have been confirmed and/or allowed as patentable over the arguments presented in the Remarks filed June 1, 2009.

Conclusion

10. **All** correspondence relating to this ex parte reexamination proceeding should be directed:

By Mail to: Mail Stop Ex Parte Reexam
Attn: Central Reexamination Unit
Commissioner for Patents
United States Patent & Trademark Office
P.O. Box 1450

Alexandria, VA 22313-1450

By FAX to: (571) 273-9900
Central Reexamination Unit

By hand: Customer Service Window
Randolph Building
401 Dulany Street
Alexandria, VA 22314

11. Registered users of EFS-Web may alternatively submit such correspondence via the electronic filing system EFS-Web, at:

https://sportal.uspto.gov/authenticate/authenticateuserlocalepf.html.

EFS-Web offers the benefit of quick submission to the particular area of the Office that needs to act on the correspondence. Also, EFS-Web submissions are "soft scanned" (i.e., electronically uploaded) directly into the official file for the reexamination proceeding, which offers parties the opportunity to review the content of their submissions after the "soft scanning" process is complete.

12. Any inquiry concerning this communication or earlier communications from the examiner, or as to the status of this proceeding, should be directed to the Central Reexamination Unit at telephone number (571) 272-7705.

Signed:

/Deandra M. Hughes/

Deandra M. Hughes
Primary Examiner
Central Reexamination Unit 3992
(571) 272-6982

Conferees:

/A. J. G./
ES K

UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF MICHIGAN
SOUTHERN DIVISION

IMRA AMERICA, INC., a Michigan corporation,	)	
Plaintiff,	)	Civil Action No.: 2:06-15139
	)	Honorable Anna Diggs Taylor
v.	)	
IPG Photonics Corporation, a Delaware corporation,	)	Magistrate Judge Mona K. Majzoub
Defendant.	)	
AND RELATED COUNTERCLAIMS	)	

ORDER REOPENING CASE AND LIFTING STAY

The Court, having heard and considered the arguments of the parties and having considered the matter, finds that there is good cause for granting the motion to reopen this case and lift the stay, and, therefore:

IT IS ORDERED THAT:

The above-captioned case is administratively reopened and the stay granted on April 3, 2008, is lifted.

DATED: October 13, 2008

s/ Anna Diggs Taylor
ANNA DIGGS TAYLOR
UNITED STATES DISTRICT JUDGE

CERTIFICATE OF SERVICE

The undersigned certifies that the foregoing Order was served upon counsel of record via the Court's ECF System to their respective email addresses or First Class U.S. mail disclosed on the Notice of Electronic Filing on October 13, 2009.

s/Johnetta M. Curry-Williams
Case Manager

US005818630C1

(12) **EX PARTE REEXAMINATION CERTIFICATE** (7121st)

United States Patent

Fermann et al.

(10) **Number: US 5,818,630 C1**

(45) **Certificate Issued: Oct. 27, 2009**

(54) **SINGLE-MODE AMPLIFIERS AND COMPRESSORS BASED ON MULTI-MODE FIBERS**

(75) Inventors: **Martin E. Fermann**, Ann Arbor, MI (US); **Donald J. Harter**, Ann Arbor, MI (US)

(73) Assignee: **Imra America, Inc.**, Ann Arbor, MI (US)

Reexamination Request:

No. 90/008,971, Mar. 12, 2008

Reexamination Certificate for:

Patent No.:	**5,818,630**
Issued:	**Oct. 6, 1998**
Appl. No.:	**08/882,349**
Filed:	**Jun. 25, 1997**

(51) **Int. Cl.**

H01S 3/06	(2006.01)
H01S 3/067	(2006.01)
H01S 3/094	(2006.01)
H01S 3/08	(2006.01)
H01S 3/23	(2006.01)
G02F 1/35	(2006.01)
G02F 1/37	(2006.01)

(52) **U.S. Cl.** **359/341.31**; 359/340; 372/19; 398/143

(58) **Field of Classification Search** .... None

See application file for complete search history.

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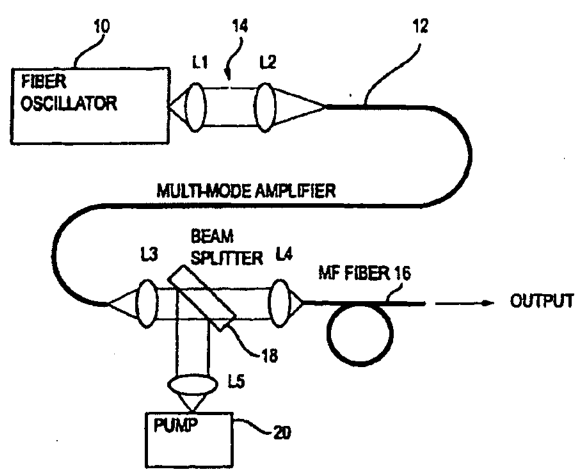
(Continued)

Primary Examiner—Deandra M Hughes

(57) **ABSTRACT**

To amplify and compress optical pulses in a multi-mode (MM) optical fiber, a single-mode is launched into the MM fiber by matching the modal profile of the fundamental mode of the MM fiber with a diffraction-limited optical mode at the launch end. The fundamental mode is preserved in the MM fiber by minimizing mode-coupling by using relatively short lengths of step-index MM fibers with a few hundred modes and by minimizing fiber perturbations. Doping is confined to the center of the fiber core to preferentially amplify the fundamental mode, to reduce amplified spontaneous emission and to allow gain-guiding of the fundamental mode. Gain-guiding allows for the design of systems with length-dependent and power-dependent diameters of the fundamental mode. To allow pumping with high-power laser diodes, a double-clad amplifier structure is employed. For applications in nonlinear pulse-compression, self phase modulation and dispersion in the optical fibers can be exploited. High-power optical pulses may be linearly compressed using bulk optics dispersive delay lines or by chirped fiber Bragg gratings written directly into the SM or MM optical fiber. High-power cw lasers operating in a single near-diffraction-limited mode may by constructed from MM fibers by incorporating effective mode-filters into the laser cavity. Regenerative fiber amplifiers may be constructed from MM fibers by careful control of the recirculating mode. Higher-power Q-switched fiber lasers may be constructed by exploiting the large energy stored in MM fiber amplifiers.



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* cited by examiner

EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

The patentability of claims **1–49** is confirmed.

New claims **50–64** are added and determined to be patentable.

50. An optical amplification system according to claim 1, wherein said mode converter comprises an optical fiber spliced to an input of said multimode fiber.

51. The optical amplification system according to claim 50, wherein said spliced fiber comprises a single-mode fiber, and wherein the mode of the single mode fiber is matched to the fundamental mode of said multi-mode amplifier.

52. An optical amplification system, comprising:

a laser source generating an input beam having a nearly diffraction limited mode;

a multi-mode fiber amplifier, said multi-mode fiber amplifier comprising a bent fiber having a bend radius in the range from about 5 cm to 50 cm;

a mode converter receiving the input beam and converting the mode of the input beam to match a fundamental mode of the multi-mode fiber amplifier, and providing a mode-converted input beam to said multi-mode fiber amplifier; and

a pump source coupled to said multi-mode fiber amplifier, said pump optically pumping said multi-mode fiber amplifier, said multi-mode fiber amplifier providing at an output thereof an amplified beam substantially in the fundamental mode.

53. An optical amplification system, comprising:

a laser source generating an input beam having a nearly diffraction limited mode;

a multi-mode fiber amplifier;

a mode converter receiving the input beam and converting the mode of the input beam to match a fundamental mode of the multi-mode fiber amplifier, and providing a mode-converted input beam to said multi-mode fiber amplifier; and

a pump source coupled to said multi-mode fiber amplifier, said pump optically pumping said multi-mode fiber amplifier, said multi-mode fiber amplifier providing at an output thereof an amplified beam substantially in the fundamental mode, and wherein said multi-mode fiber amplifier is configured to substantially eliminate mode coupling during propagation of said mode converted beam in said multi-mode fiber amplifier.

54. The optical amplification system according to claim 53, wherein said mode coupling couples less than 6% of the fundamental mode to one or more higher order modes.

55. An optical amplification system, comprising:

a laser source generating an input beam having a nearly diffraction limited mode;

a multi-mode fiber amplifier;

a mode converter receiving the input beam and converting the mode of the input beam to match a fundamental mode of the multi-mode fiber amplifier, and providing a mode-converted input beam to said multi-mode fiber amplifier;

a pump source coupled to said multi-mode fiber amplifier, said pump optically pumping said multi-mode fiber amplifier, said multi-mode fiber amplifier providing at an output thereof an amplified beam substantially in the fundamental mode; and

a single mode fiber receiving the amplified beam.

56. The optical amplification system according to claim 55, wherein a coupling efficiency between said amplifier and said single mode fiber is about 90%.

57. The optical amplification system according to claim 55, wherein said multi-mode amplifier is substantially straight.

58. The optical amplification system according to claim 55, wherein said amplifier is configured with a sufficient thickness to limit bend induced mode coupling.

59. An optical amplification system, comprising:

a laser source generating an input beam having a nearly diffraction limited mode, said laser source comprising a cw fiber laser;

a multi-mode fiber amplifier;

a mode converter receiving the input beam and converting the mode of the input beam to match a fundamental mode of the multi-mode fiber amplifier, and providing a mode-converted input beam to said multi-mode fiber amplifier; and

a pump source coupled to said multi-mode fiber amplifier, said pump optically pumping said multi-mode fiber amplifier, said multi-mode fiber amplifier providing at an output thereof an amplified beam substantially in the fundamental mode.

60. The optical amplification system according to claim 59, wherein said cw fiber laser comprises a multi-mode fiber amplifier.

61. The optical amplification system according to claim 59, wherein said cw fiber laser comprises an intracavity mode filter.

62. The optical amplification system according to claim 59, further comprising at least one pre-amplifier disposed between said source and said multi-mode fiber amplifier.

63. The optical amplification system according to claim 62, wherein a core radius of said pre-amplifier is smaller than a radius of said multimode fiber amplifier.

64. An optical amplification system, comprising:

a laser source generating an input beam having a nearly diffraction limited mode;

a multi-mode fiber amplifier;

a mode converter receiving the input beam and converting the mode of the input beam to match a fundamental mode of the multi-mode fiber amplifier, and providing a mode-converted input beam to said multi-mode fiber amplifier; and

a pump source coupled to said multi-mode fiber amplifier, said pump optically pumping said multi-mode fiber amplifier, said multi-mode fiber amplifier providing at an output thereof an amplified beam substantially in the fundamental mode, and wherein said multi-mode fiber amplifier is configured to provide a nearly diffraction limited output beam.

* * * * *

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
90/010,650	08/19/2009	5818630	16577-0003RX2	8198

7590 11/13/2009

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EXAMINER

ART UNIT	PAPER NUMBER

DATE MAILED: 11/13/2009

Please find below and/or attached an Office communication concerning this application or proceeding.

Order Granting / Denying Request For Ex Parte Reexamination	Control No. 90/010,650	Patent Under Reexamination 5818630	
	Examiner Deandra M. Hughes	Art Unit 3992	

--The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

The request for *ex parte* reexamination filed *19 August 2009* has been considered and a determination has been made. An identification of the claims, the references relied upon, and the rationale supporting the determination are attached.

Attachments: a)☐ PTO-892, b)☒ PTO/SB/08, c)☐ Other: _____

1. ☐ The request for *ex parte* reexamination is GRANTED.

RESPONSE TIMES ARE SET AS FOLLOWS:

For Patent Owner's Statement (Optional): TWO MONTHS from the mailing date of this communication (37 CFR 1.530 (b)). **EXTENSIONS OF TIME ARE GOVERNED BY 37 CFR 1.550(c).**

For Requester's Reply (optional): TWO MONTHS from the **date of service** of any timely filed Patent Owner's Statement (37 CFR 1.535). **NO EXTENSION OF THIS TIME PERIOD IS PERMITTED.** If Patent Owner does not file a timely statement under 37 CFR 1.530(b), then no reply by requester is permitted.

2. ☒ The request for *ex parte* reexamination is DENIED.

This decision is not appealable (35 U.S.C. 303(c)). Requester may seek review by petition to the Commissioner under 37 CFR 1.181 within ONE MONTH from the mailing date of this communication (37 CFR 1.515(c)). **EXTENSION OF TIME TO FILE SUCH A PETITION UNDER 37 CFR 1.181 ARE AVAILABLE ONLY BY PETITION TO SUSPEND OR WAIVE THE REGULATIONS UNDER 37 CFR 1.183.**

In due course, a refund under 37 CFR 1.26 (c) will be made to requester:

a) ☐ by Treasury check or,

b) ☐ by credit to Deposit Account No. _____, or

c) ☐ by credit to a credit card account, unless otherwise notified (35 U.S.C. 303(c)).

/Deandra M Hughes/ Primary Examiner, Art Unit 3992		

cc:Requester (if third party requester)

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EX PARTE REEXAMINATION COMMUNICATION TRANSMITTAL FORM

REEXAMINATION CONTROL NO. 90/010,650.

PATENT NO. 5818630.

ART UNIT 3992.

Enclosed is a copy of the latest communication from the United States Patent and Trademark Office in the above identified *ex parte* reexamination proceeding (37 CFR 1.550(f)).

Where this copy is supplied after the reply by requester, 37 CFR 1.535, or the time for filing a reply has passed, no submission on behalf of the *ex parte* reexamination requester will be acknowledged or considered (37 CFR 1.550(g)).

ORDER DENYING REQUEST FOR *EX PARTE* REEXAMINATION

1. Substantial new questions of patentability ("**SNQ**") affecting **claims 1-3, 10-12, 24-25, 27-29, 31, 36-37, 39, and 46-49** of **USP 5,818,630** ("**Fermann**") have been proposed by the third party requester ("**3PR**") in the *ex parte* reexamination request filed 19, 2009 ("**Request**").

2. This is the second request for reexamination of the **Fermann** patent. The first request (90/008,971) was filed on March 12, 2008. A Notice of Intent to Issue Rexam Certificate ("NIRC") was mailed on July 21, 2009. In the 1st reexamination, **claims 1-49** were confirmed as patentable and **claims 50-64** were allowed as patentable.

3. Since this request is the second request for ex parte reexamination of the **Fermann** patent, the order will be granted *only if the prior art cited raises a SNQ which is different from that is raised in the previous reexamination proceeding* (90/008,971). Please see MPEP §2240(II) wherein it states:

> "If a second or subsequent request for ex parte reexamination is filed (by any party) while a first ex parte reexamination is pending, the presence of a substantial new question of patentability depends on the prior art (patents and printed publications) cited by the second or subsequent requester. If the requester includes in the second or subsequent request prior art which raised a substantial new question in the pending reexamination, *reexamination should be ordered only if the prior art cited raises a substantial new question of patentability which is different from that raised in the pending reexamination proceeding. If the prior art cited raises the same substantial new question of patentability as that raised in the pending reexamination proceedings, the second or subsequent request should be denied.* Where the request raises a different substantial new question of patentability as to some patent claims, but not as to others, the request would be granted in part..."
>
> The second or subsequent request for reexamination may provide information raising a substantial new question of patentability with respect to any new or amended claim which has been proposed under 37 CFR 1.530(d) in the first (or prior) pending reexamination proceeding. However, in order for the second or

subsequent request for reexamination to be granted, the second or subsequent requester must independently provide a substantial new question of patentability which is different from that raised in the pending reexamination for the claims in effect at the time of the determination. The decision on the second or subsequent request is thus based on the claims in effect at the time of the determination (37 CFR 1.515(a)). If a 'different' substantial new question of patentability is not provided by the second or subsequent request for the claims in effect at the time of the determination, the second or subsequent request for reexamination must be denied since the Office is only authorized by statute to grant a reexamination proceeding based on a substantial new question of patentability 'affecting any claim of the patent.' See 35 U.S.C. 303. Accordingly, there must be at least one substantial new question of patentability established for the existing claims in the patent in order to grant reexamination. Once the second or subsequent request has provided a 'different' substantial new question of patentability based on the claims in effect at the time of the determination, the second or subsequent request for reexamination may also provide information directed to any proposed new or amended claim in the pending reexamination, to permit examination of the entire patent package. The information directed to a proposed new or amended claim in the pending reexamination is addressed during the later filed reexamination (where a substantial new question of patentability is raised in the later filed request for reexamination for the existing claims in the patent), in order to permit examination of the entire patent package. When a proper basis for the second or subsequent request for reexamination is established, it would be a waste of resources to prevent addressing the proposed new or amended claims, by requiring parties to wait until the certificate issues for the proposed new or amended claims, and only then to file a new reexamination request challenging the claims as revised via the certificate. This also prevents a patent owner from simply amending all the claims in some nominal fashion to preclude a subsequent reexamination request during the pendency of the reexamination proceeding."

Here, the 'pending reexamination proceeding' is 90/008,971. In the '971 proceeding, a NIRC was mailed July 21, 2009. However, the Reexamination Certificate has not yet published. Accordingly, the instant reexamination request appropriately does not address the added **claims 50-64** in the '971 proceeding.

References Cited in this Action

4. Digonnet, Michel J.F. Passive and Active Fiber Optic Components. ("**Digonnet**")

5. Desthieux et al. "111 kW (05mJ) pulse amplification at 1.5 µm using a gated cased of three erbium-doped fiber amplifiers." ("**Desthieux**")

6. USP 5,422,897 to Wyatt et al. published Jun. 6, 1995. ("**Wyatt**")

7. 37 CFR §1.132 Declaration of Dr. Philip H. Bucksbaum ("**Bucksbaum Declaration**")

Please note that **Digonnet** and **Desthieux** were cited in the first (90/008,971) reexamination request of **Fermann**.

Prosecution History

8. The prosecution history of the application (08/989,261) which became the **Fermann** patent is presented below.

Claims 1-49 are the current claims in the **Fermann** patent which issued Oct. 6, 1998 from application (08/882,349) Jun. 25, 1997.

Of the claims for which reexamination is requested, **claim 1** is independent. All claims were indicated as allowed in a first action Notice of Allowance (5/26/1998). The examiner indicated the claims to be allowed because the prior art does not teach or fairly suggest an optical amplifier with near diffraction limited input, a mode converter, a pump, and a multi-mode amplifier with output in the fundamental mode.

Although not specifically pointed out by the original examiner, it is considered that the near diffraction limited input and the pump would be fairy conventional, such that the combination of the mode converter and the multi- mode amplifier with output in the fundamental mode would be considered as the critical elements related to patentability.

As such, the Examiner considers the teachings as to the following limitations of **claim 1** to form the basis of a SNQ:

(a) a mode converter receiving the input beam and converting the mode of the input beam to match a fundamental mode of the multi-mode fiber amplifier, and providing a mode-converted input beam to said multi-mode fiber amplifier;

(b) said multimode fiber amplifier providing at an output thereof an amplified beam substantially in the fundamental mode.

9. 3PR proposes seventeen SNQs based on **Digonnet** and **Desthieux** as primary references (Request, pgs. 7-9). 3PR argues that although **Digonnet** was considered in the '971 proceeding, "the Office did not appreciate the true content of the Digonnet reference." (Request, pg. 29, 2nd ¶). Further, 3PR argues that although **Desthieux** was considered in the '971 proceeding, "the Office failed to appreciate the full scope and content of the **Digonnet** thesis during the '971 proceeding. Accordingly, **Desthieux**, when modified by **Digonnet** thesis as correctly interpreted, raises a substantial new question of patentability." (Request, pg. 50, 1st ¶). 3PR alleges the **Bucksbaum Declaration** presents **Digonnet** and **Desthieux** in a new light and as such, **Digonnet** and **Desthieux,** when considered in the light of the **Bucksbaum Declaration** present SNQs as to the claims of the **Fermann** patent.

Decision

--Digonnet--

10. As to the SNQs with **Digonnet** as the primary reference, the request for reexamination is DENIED for the following reasons.

As was explained above, the Examiner considers teachings as to the following limitations of **claim 1** to form the basis of a SNQ:

(a) a mode converter receiving the input beam and converting the mode of the input beam to match a fundamental mode of the multi-mode fiber

amplifier, and providing a mode-converted input beam to said multi-mode fiber amplifier;

(b) said multimode fiber amplifier providing at an output thereof an amplified beam substantially in the fundamental mode.

A SNQ is not raised because **claim 1** was found to be patentable over **Digonnet** in the '971 proceeding and **Digonnet** is not presented in a new light in the instant Request. 3PR submits the **Bucksbaum Declaration** to present the teachings of **Digonnet** in a new light.[1]

However, the **Bucksbaum Declaration** does not present **Digonnet** in a new light because it merely repeats the teachings that were thoroughly considered in the '971 proceeding as to the interfacing optics of **Digonnet**. First, the **Bucksbaum Declaration** cites *the same* interfacing optics disclosed in page 129 of **Digonnet** alleging that a reasonable Examiner would consider this teaching important in determining whether **claim 1** is patentable. (compare **Bucksbaum Declaration**, pgs. 18-20 ¶¶48-53 to the Request of the '971 proceeding, pg. 107) Since the **Bucksbaum Declaration** merely summarizes the disclosure of **Digonnet**, which was thoroughly considered in the '971 proceeding, the Examiner is not persuaded that the **Bucksbaum Declaration** presents **Digonnet** in a new light as to limitation **(a)** above.

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[1] In the '971 proceeding, the Examiner did not patentably distinguish **Digonnet**'s interfacing optics from the claimed mode-converter. **Digonnet** was distinguished from the claimed invention because **Digonnet** did not teach or suggest *said multimode amplifier providing an output thereof of an amplified beam substantially in the fundamental mode*. (see Non-Final Action mailed 3/30/09; pg. 5; emphasis added).

Second, the **Bucksbaum Declaration** alleges that **Digonnet** "describes a multi-mode fiber amplifier that provides an amplified beam at its output that is substantially in the fundamental mode." (pg. 22, ¶56). As support, the **Bucksbaum Declaration** states:

> "...the **Digonnet** thesis describes a scheme in which a SM input beam 'excites' or is 'launched' in the fundamental mode of a MM active fiber. As the SM beam propagates through the MM fiber, it is amplified. *By minimizing imperfections in the MM fiber, an amplified input beam emerges which is substantially in the fundamental mode*." (pg. 23, ¶57; emphasis added)

To form the basis of an SNQ, **Digonnet** must teach or fairly suggest limitation **(b)** above. **Digonnet** was patentably distinguished from **claim 1** in the '971 proceeding based on limitation **(b)**. The Examiner stated, *inter alia*:

> "As a result, when the signal exits the device of **Digonnet**, the signal power of the fundamental mode is the same as before it was excited at the input port. However, the remaining energy would be mode-coupled to the higher modes thereby resulting in an output comprising the fundamental mode and the higher modes that received energy via mode-coupling." (Non-Final Action mailed 3/30/09; pg. 6, last ¶)

Here, the **Bucksbaum Declaration** attempts to present **Digonnet** in a new light stating "[b]y minimizing imperfections in the MM fiber, an amplified input beam emerges which is substantially in the fundamental mode", without any citation to **Digonnet** as to *how* **Digonnet** minimized imperfections in the MM fiber so that the amplified beam emerges which is substantially in the fundamental mode.

The **Bucksbaum Declaration** makes this conclusory statement without stating *where* **Digonnet** has taught or fairly suggested an MM fiber with minimized imperfections so that the beam emerges which is substantially in the fundamental mode (pg. 23, ¶¶57 and 82-95) Notably, the inventors of the **Fermann** patent thoroughly discuss the need in the art for a MM fiber in which mode-coupling is minimized or

controlled. (e.g., col. 2:6-7, 14-15, 60-65; col. 3, 53-56, 63-67, col.4:5-15). Further, a substantial portion of the **Fermann** patent is directed to minimizing this mode-coupling problem in MM fibers. And most importantly, the **Fermann** patent expressly claims *a multimode fiber amplifier providing at the output thereof of amplified beam substantially in the fundamental mode.*

The **Bucksbaum Declaration** admits that both **Digonnet** and the **Fermann** patent recognize mode-coupling due to imperfections in the MM fiber as a problem in the art. The **Bucksbaum Declaration** then alleges that **Digonnet** teaches how to reduce imperfections in the MM fiber to reduce mode coupling so that the beam emerges from the fiber in substantially the fundamental mode (pg. 32, ¶84).

The **Bucksbaum Declaration** then inconsistently states that this problem, which was allegedly solved by **Digonnet**, continued to be recognized as a problem in the art. (e.g, pg. 33, ¶88; pg. 34, ¶91). Michel J.F. Digonnet is a preeminent scholar in the field of fiber optics and has obtained more than 100 patents in the art spanning over 25 years. However, the **Bucksbaum Declaration** alleges that **Digonnet** disclosed the solution to the problem of how to minimize imperfections in a MM amplifying fiber to provide an output there of an amplified beam substantially in the fundamental mode and yet those of ordinary skill in the art continued to try to solve this problem despite an alleged disclosed solution by a preeminent scholar and inventor in the art. [2]

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[2] The **Digonnet** thesis was published in 1983. The **Bucksbaum Declaration** admits that **Wyatt**, which was filed in 1994, continued to recognize the problem. (pg. 33, ¶89)

As such, the Examiner is not persuaded that the **Digonnet** reference teaches or fairly suggests *a multimode fiber amplifier providing at the output thereof of amplified beam substantially in the fundamental mode* because the **Bucksbaum Declaration** expressly admits that those of ordinary skill in the art continued to recognize the need to solve the problem long after the alleged disclosure of the solution by a pre-eminent scholar and inventor in the field. (pg. 33, ¶¶88-89) The Examiner considers this admission by the **Bucksbaum Declaration** to be evidence that the **Digonnet** reference did not disclose the solution to the problem of how to minimize imperfections in a MM amplifying fiber to provide an output there of an amplified beam substantially in the fundamental mode. Consequently, the SNQs for which **Digonnet** is the primary reference is DENIED because **Digonnet** has been thoroughly considered in the '971 proceeding and the **Bucksbaum Declaration** does not present **Digonnet** in a new light.

--Desthieux--

11. As to the SNQs with **Desthieux** as the primary reference, the request for reexamination is DENIED for the following reasons.

As was explained above, the Examiner considers teachings as to the following limitations of **claim 1** to form the basis of a SNQ:

(a) a mode converter receiving the input beam and converting the mode of the input beam to match a fundamental mode of the multi-mode fiber amplifier, and providing a mode-converted input beam to said multi-mode fiber amplifier;

(b) said multimode fiber amplifier providing at an output thereof an amplified beam substantially in the fundamental mode.

A SNQ is not raised because **<u>claim 1</u>** was found to be patentable over **Desthieux** in the '971 proceeding and **Desthieux** is not presented in a new light in the instant Request. 3PR submits the **Bucksbaum Declaration** to present the teachings of **Desthieux** in a new light.[3]

However, the **Bucksbaum Declaration** does not present **Desthieux** in a new light because it merely repeats the teachings that were thoroughly considered in the '971 proceeding as to the interfacing optics of **Desthieux**. First, the **Bucksbaum Declaration** cites *the same* interfacing optics disclosed in <u>figure 1</u> of **Desthieux** alleging that a reasonable Examiner would consider this teaching important in determining whether **claim 1** is patentable. (<u>compare **Bucksbaum Declaration**, pg. 38 ¶¶103 to the Request of the '971 proceeding, pg. 83</u>) Since the **Bucksbaum Declaration** merely summarizes the disclosure of **Desthieux**, which was thoroughly considered in the '971 proceeding, the Examiner is not persuaded that the **Bucksbaum Declaration** presents **Desthieux** in a new light as to limitation **(a)** above.

Second, the Request states "a POSITA at the time of the alleged invention would have further understood **Desthieux** to disclose the output from EDFA3 to be substantially in the fundamental mode" because:

(i) the MM fiber in EDFA3 is short, i.e. 1.7m long;

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[3] In the '971 proceeding, the Examiner did not patentably distinguish **Desthieux**'s interfacing optics from the claimed mode-converter. **Destheiux** was distinguished from the claimed invention because **Desthieux** did not teach or suggest *said multimode amplifier providing an output thereof of an amplified beam <u>substantially in the fundamental mode</u>*. (<u>see Non-Final Action mailed 3/30/09; pgs. 9-11; emphasis added</u>).

(ii) **Desthiuex** specifically mentions reducing the numerical aperture of EDFA to NA=0.12 to minimize fiber modes; and

(iii) the amplifying fiber in EDFA3 is an amorphous glass fiber. (pg. 52, 3rd ¶ and).

The novelty rule, i.e. anticipation, requires that a *single prior art* reference require, expressly or inherently, each and every feature of the claimed invention. Here, 3PR admits that **Desthieux** does not expressly disclose the claimed feature of *a multimode fiber amplifier providing at the output thereof of amplified beam substantially in the fundamental mode.* (Request, pg. 104, 2nd ¶). However, 3PR alleges that one of ordinary skill in the art would nonetheless understand **Desthieux** to disclose this claimed feature. (Request, pg. 52, 3rd ¶).

3PR relies on the **Bucksbaum Declaration** to present **Desthieux** in this new light. (Bucksbaum Declaration; pg. 40, ¶110) Consequently, the crux of 3PR's SNQ is that although **Desthieux** does not *expressly* disclose this feature, it *inherently* discloses this feature as is supported by the **Bucksbaum Declaration.**[4]

3PR presented the same SNQ in the Request of the previous proceeding wherein 3PR stated:

> "Desthieux does not *explicitly* state the spatial quality of the output from the third multimode EDFA (and as described above, we submit that a POSITA would nonetheless understand Desthieux to disclose an output substantially in the fundamental mode." ('971 Proceeding Request; pg. 85, 2nd ¶; emphasis original)

[4] Note, 3PR states "a POSITA at the time of the alleged invention would have further understood **Desthieux** to disclose the output from EDFA3 to be substantially in the fundamental mode." As such, 3PR is alleging an SNQ based on anticipation. (see Request, pg. 52, 3rd ¶)

However, in the '971 proceeding Request 3PR relied on different facts to support its SNQ on this allegedly inherent feature. ('971 Proceeding Request; pg. 85, 1st ¶) These facts were that for the output beam, as disclosed on pg. 587, column 1 of **Desthieux**:

(i) the maximum output power obtained was 111kW;

(ii) using 10ns quasisquare input pulse of peak power;

(iii) of 1.53 mW at a repetition frequency rate of 400Hz;

(iv) [which] corresponds to a net amplifier gain of 78.6 db.

In the instant Request, 3PR attempts to present **Desthieux** in a new light via the **Bucksbaum Declaration** wherein the **Bucksbaum Declaration** relies on a different set of facts to support this alleged inherency.

In order for a prior art reference to inherently disclose a claimed feature, the prior art disclosure must *necessarily* include the inherent (unexpressed) subject matter. The inherent subject matter must not be occasionally present or accidentally present, the inherent subject matter must be inevitable from the prior art reference's disclosure. *Tilghman v. Proctor*, 102 U.S. 707 (1880). Here, the **Bucksbaum Declaration** does not present the **Desthieux** reference in a new light because the **Bucksbaum Declaration** does not present any analysis as to *why* a 1.7m long MM EDFA amorphous glass fiber with a NA of 0.12 would *necessarily* provide an output beam that is substantially in the fundamental mode. (see **Bucksbaum Declaration**, pg. 40-41, ¶110).

Notably, the **Bucksbaum Declaration** merely states, without any analysis at all, that based on these facts, he understands **Desthieux** "to have taken steps to minimize mode coupling that *might* otherwise prevent the output from being maintained in the fundamental mode." (pg. 41, lines 1-3). A statement that minimizing "mode coupling

that *might* otherwise prevent the output from being maintained in the fundamental mode" is clearly not a statement that the EDFA3 *necessarily* produces an amplified beam substantially in the fundamental mode.[5] As such, the **Bucksbaum Declaration** is insufficient to present **Desthieux** in a new light as to claim limitation **(b)** above.

In the alternative, 3PR proposes SNQs based on the combinations of, at least, **Desthieux** and **Digonnet**. (Request, pg. 104, 3rd ¶). For the reasons set forth above, **Digonnet** has not been presented in a new light. Since **Desthieux** and **Digonnet** have been thoroughly considered in the '971 proceeding and the **Bucksbaum Declaration** fails to present these references in a new light, the request for reexamination based on proposed SNQs on the combinations of **Desthieux** and **Digonnet** is DENIED.

Conclusion

12. **All** correspondence relating to this *ex parte* reexamination proceeding should be directed:

By Mail to: Mail Stop *Ex Parte* Reexam
Attn: Central Reexamination Unit

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[5] The Examiner notes that the Request cites **Desthieux** pg. 586, bottom of col. 1 for the disclosure of a 1.7m long, amorphous silica fiber with a NA of 0.12 alleging that these facts disclose that "a POSITA at the time of the alleged invention would have further understood **Desthieux** to disclose the output from EDFA3 to be substantially in the fundamental mode."

Yet, both the Request and the **Bucksbaum Declaration** fail to address in any way the remainder of the sentence in the **Desthieux** disclosure wherein it states the EDFA3 "supported ***~20 modes at both the pump and signal wavelengths***." (Compare Desthieux, pg. 586, end of col. 2 continuing to pg. 587 beginning of col. 1 to Request, pg. 52, 3rd ¶ and Bucksbaum Declaration, pg. 40, ¶110)

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By FAX to: (571) 273-9900
Central Reexamination Unit

By hand: Customer Service Window
Randolph Building
401 Dulany Street
Alexandria, VA 22314

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Any inquiry concerning this communication or earlier communications from the examiner, or as to the status of this proceeding, should be directed to the Central Reexamination Unit at telephone number (571) 272-7705.

Signed: Conferees:

ESK
Wgz

/Deandra M. Hughes/
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